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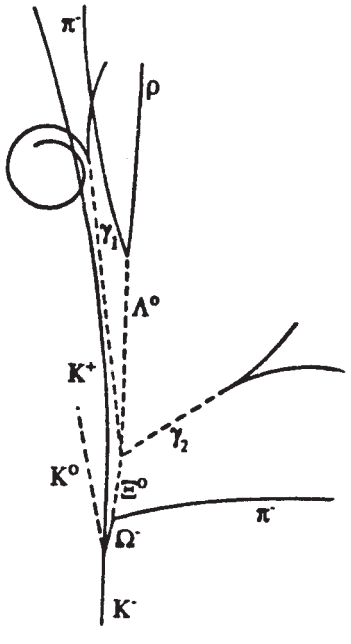

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HADRONIC PARADIGM REASSESSED: NEUTROID AND NEUTRON SYNTHESIS FROM AN ARC OF CURRENT IN HYDROGEN GAS, 119

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Abstract

The hadronic paradigm may be reassessed around the evidence gathered in an inexpensive and easily replicable experiment where neutrons and an intermediate spin zero state prior to the full neutron synthesis known as *neutroids* are synthesized from an arc of current in hydrogen gas. We will review the history of this experiment in its various forms, as well as offer a recounting of the history related to neutrino theory in order to then provide an alternative model which rightly fits experimental results. Once quantum theory and hadronic science admits these experimentally derived conflicts and solutions, then the new paradigm offered in *Hadronic Mechanics* and *Hadronic Chemistry* may allow for new sources of energy and the stimulated decay of nuclear waste.

Key words: Neutron, Neutroid, Hadron, Rutherford, Hydrogen

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I. INTRODUCTION AND HISTORY.

Although quantum theory is unquestionably one of mankind's greatest and most useful achievements, it must be remembered that even its most accurate inculcation as demonstrated in Quantum Electro Dynamics (QED) does not proceed from a firm causal basis, as it is renormalized [1] (p. 128). This situation admits new possibilities which might more closely approach the truth in order to create new solutions to the intransigent problems which have beset mankind. Hadronic science offers us just such a new avenue where a simple and easily replicable experiment could allow insight permitting paradigm adjustment and new solutions. Toward that end, we will first review the experimental history of the synthesis of neutrons and an intermediate spin zero state prior to the full neutron synthesis known as *neutroids* (see section so named below) from an arc of current in hydrogen gas proceeding conceptually and experimentally from Rutherford to Ernest Sternglass, Edward Trounson then Don Carlo Borghi and R. M. Santilli, after which we will articulate the overarching implications for theoretical physics.

Rutherford (1920) [2] first proposed the notion that neutrons might actually be synthesized within the furnace of stars as compressed hydrogen atoms:

$$p^+ + e^- \rightarrow n, \tag{1}$$

as Chadwick [3] experimentally confirmed in (1932):

$$p^+ + e^- \rightarrow n + \nu\ , \tag{2}$$

where ν symbolizes a neutrino, meaning "little neutral one." The neutral charge, zero mass neutrino was proposed by Wolfgang Pauli under the name of neutron [4,5,6] so as to account for how beta decay conserves energy, momentum and angular momentum, even though Pauli had such severe reservations [4] as to call his proposed solution a "desperate remedy." Later Pauli's "neutron" was renamed as the "neutrino" by Enrico Fermi [7], a name humorously suggested by Eduardo Amaldi [8,9] to avoid subsequent confusion after Chadwick's discovery [3] of the neutron proper in 1932 [7,8,9,10]. It should be remembered that, although great expense has been incurred attempting to detect neutrinos directly, no direct detection of neutrinos has ever occurred; their "existence" has been ***inferred entirely from signature effects*** involving gamma ray production from electron

positron annihilation and also gamma ray production stemming from cadmium neutron interactivity, allowing signature-specific timing differentiation between two supposedly neutrino induced gamma sources [11].

In assessing the likely plausibility of his own "desperate" solution, we read (translated) from his 1930 communication to the *Physical Institute of the Federal Institute of Technology*, Zurich [4]:

" . . . I have hit upon a desperate remedy to save the "exchange theorem" of statistics and the law of conservation of energy. . . . I admit that my remedy may seem almost improbable because one probably would have seen those neutrons [here meaning neutrinos], if they exist, for a long time. "

Also, on the Berkley Center for Theoretical Physics web site [7*a*] we find:
"Because neutrinos interact so weakly with matter, Pauli bet a case of champagne that nobody would ever detect one."

II. EXPERIMENTAL RESULTS.

The initial successful synthesis of neutroids from an arc of current in hydrogen gas and subsequent synthesis of neutrons by a process of substance-specific nuclear transmutation was performed by Earnest Sternglass in 1951 while completing his Ph.D. thesis at Cornell. He wrote to Einstein of his inexplicable results, which seemed to occur in conditions lacking sufficient energy to synthesize the neutrons his experiments had indeed somehow apparently created.

From the Rare Manuscript Collection division of Cornell University Library as represented in [12]:

Ithaca, N.Y.
August 26th, 1951
518 Dryden Rd.

Dear Professor Einstein,

You may be interested to learn that in the course of the past two months I have been able to obtain experimental evidence for the formation of neutrons from protons and electrons in a high-voltage hydrogen discharge.

The experiments were carried out with a demountable gas X-ray tube capable of dissipating 1,200 watts filled with hydrogen and surrounded by about 6 inches of paraffin on all sides. Voltages up to 35 kV and currents up to 40 mA were used and silver and indium foils were placed near the tube walls. The neutron induced beta--activities were measured with a thin-walled aluminum Geiger-Muller counter in a lead housing of about 3-4" thickness giving a background count of 15 counts per minute. The initial activities in indium and silver were found to be 6--7 counts above background, decaying with the respective mean lives of 2.4 min for Ag and 54 min. for In. Having a standard neutron source, this arrangement could be calibrated roughly so that the rate of neutron formation can be determined to be on the order of 10--20 neutrons/sec at 38 mA and 25 kV and an estimated pressure of 10^{-2} mm of mercury in the discharge.

The possibilities of cosmic--ray produced neutrons was eliminated by exposing the foils without turning the discharge on. Contamination of anode & cathode with materials that could give rise to neutrons was eliminated by replacing them with freshly machined parts. The possibility of a deuteron--deuteron reaction was eliminated by a calculation using famous values of the cross--section for this process leading to a factor of 10^{5}-10^{6} too small a rate of neutron formation by the slight admixture of deuterium in normal hydrogen. So far, no one in the department here has been able to suggest any nuclear reaction that could be made to account for the activity at such a low energy. During the next few weeks we intend to make measurements on the activities in a salt--mine, 2000 ft. below ground as to improve the statistics of our counts. Professor Cocconi and Professor Ieiri will setup the equipment for this experiment after which we shall feel ready to announce it possibly at the Chicago meeting.

The indicated rate of formation is consistent with a cross-section of 2.5×10^{-24} cm^2 for the case of an isolated proton capturing an electron in the process calculated by C.G. Darwin in 1913. It is not consistent with the cross--section of 10^{-42} cm^2 predicted by neutrino theory. This seams to lend strongly support to the view that the neutron is a purely electromagnetic entity composed of a proton and a highly "distorted" electron as I have outlined to you in my last letter.

I remain sincerely yours,

Ernest J. Sternglass [12] (pp. 8-9)

Although Einstein firmly advised that the results must be published even though they apparently contradicted standard theory, Sternglass refused due to the stultifying preponderance of contrary opinion and so, his results were preemptively excluded under orthodox pressure within the discipline [12,13] leaving them unpublished. Edward Trounson, a physicist working at the Naval Ordnance Laboratory repeated the experiment and again gained successful results but they too, were not published [12,13].

It will be demonstrated that Sternglass' experiments could only have synthesized *neutroids*, which were then subsequently transformed into neutrons by a process of substance-specific nuclear transmutation. (See the section entitled *Neutroids* below.)

The next to synthesize neutroids and hence neutrons via an intermediate process of substance-specific nuclear transmutation was Don Carlo Borghi. His seminal experiment involved a cylindrical metal chamber named a "klystron," containing low pressure hydrogen gas irradiated with microwaves at $10^{10}\ s^{-1}$ frequency and also using an electric arc of 500 V and 10 mA [14]. Santilli [14*a*, 15] later discovered that microwave irradiation of the gas was not necessary to create the experimental effects, although the influence of such radiation was not excluded as to its possible contributory influence. In both the experiments of Don Carlo Borghi and those of Santilli, *delayed neutron synthesis* was sometimes observed. From Santilli [14*a*,15]:

> "A first series of measurements was initiated with Klystron I on July 28, 2006, at 2 p.m. Following flushing of air, the klystron was filled up with commercial grade hydrogen at 25 psi pressure. We first used detector PM1703GN to verify that the background radiations were solely consisting of photon counts of 5 – 7 $\mu R/h$ without any neutron count; we delivered a DC electric arc at 27 V and 30 A (namely with power much bigger than that of the arc used in Don Borghi's tests . . .), at about 0.125" gap for about 3 s; we waited for one hour until the electrodes had cooled down; and then placed detector PM1703GN against the PVC cylinder. This resulted in the detection of photons at the rate of 10 – 15 $\mu R/h$ expected from the residual excitation of the tips of the electrodes, but no

neutron count at all.

> However, about three hours following the test, detector PM1703GN entered into sonic and vibration alarms, specifically, for neutron detections off the instrument maximum of 99 *cps* at about 5' distance from the klystron while no anomalous photon emission was measured. The detector was moved outside the laboratory and the neutron counts returned to zero. The detector was then returned to the laboratory and we were surprised to see it entering again into sonic and vibrational alarms at about 5' away from the arc chamber with the neutron count off scale without appreciable detection of photons, at which point the laboratory was evacuated for safety. After waiting for 30 m (double neutron's lifetime), we were surprised to see detector PM1703GN go off scale again in neutron counts at a distance of 10' from the experimental set up, and the laboratory was closed for the day." [14*a*,15] (Santilli, 2006 pp. 4-5, 2007 p. 715)

Neutron counts registering much higher and in these cases arising more rapidly, some necessitating the actual evacuation of the laboratory, were obtained by first increasing the arc energy to 700V and 1.2 amps via a transformer, noting closely that manual impact of the experimental device and also a triggering-implosion from oxygen admixture yielding oxygen/hydrogen combustion both dramatically increased synthesis effects. Once hydrogen pressure was stepped up to 100 psi, dangerous experimental results were assured. It appears from analysis of this first series of Santilli's experiments [14*a*, 15] that arc energies are associated with the possible delayed creation/detection of neutrons if those energies are low (by a particular mechanism to be specified), or the immediate synthesis of neutrons may be encouraged if the energies achieve some higher energetic constituency.

Alarm, neutron	9/1/2006/5:57:00 AM	99 Cps
Alarm, neutron	9/1/2006/5:58:00 AM	99 Cps
Alarm, neutron	9/1/2006/5:59:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:01:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:01:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:01:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:02:00 AM	99 Cps
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Alarm, neutron	9/1/2006/6:16:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:17:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:17:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:17:00 AM	99 Cps
Alarm, neutron	9/1/2006/6:17:00 AM	99 Cps

FIG. 1.
Print-out reproduction of a typical scan of detector PM1703GN indicating neutron alarms that required evacuation of the laboratory [15] (Santilli 2007). (Used with permission of Ruggero Santilli/Hadronic Journal).

Experimental apparatus used by Santilli in [14*a*,15] as represented in [16]:

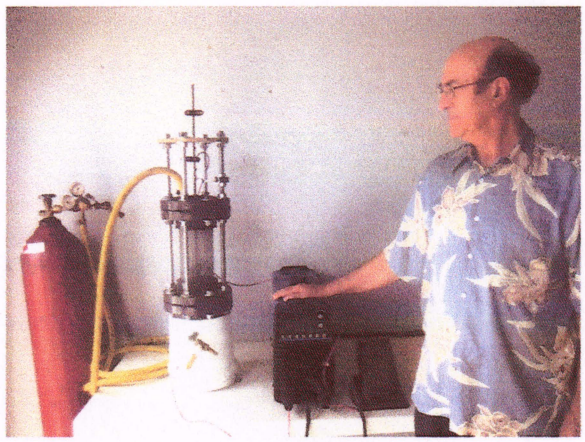

FIG. 2.
[16] (Santilli, 2014) (Used with permission of Ruggero Santilli/Journal of Computational Methods in Sciences and Engineering)

The next tests discussed [16] (Santilli, 2014) were conducted using several different more advanced pieces of experimental apparatus. (See below).

FIG. 3. Second reactor constructed with schedule 40 steel used in tests with hydrogen gas at 100 psi. [16] (Santilli, 2014). (Used with permission of Ruggero Santilli/Journal of Computational Methods in Sciences and Engineering)

FIG. 4. One experimental setup, equipment from the left: SAM 940 neutron and gamma detector; a Polimaster, a Berkeley Nucleonics PalmRad; and a Ludlum neutron and gamma detector (not shown in this figure); the reactor; the specially built rapid DC pulsing power unit (patent pending) with incorporated capacitors in it; and the hydrogen bottle. [16] (Santilli, 2014). (Used with permission of Ruggero Santilli/Journal of Computational Methods in Sciences and Engineering)

In these new experiments neutrons were synthesized immediately upon the condition that the arc energy was sufficient to exclude the production of neutroids (see section below) which are indeed excluded at energies of a ~500*J* [16]. Santilli states in regard to the striking result concerning synthesis of thermal neutrons: ". . . a reactor comprising an essentially pure hydrogen gas at 30 psi, when exposed to a high voltage DC discharge with about 3 kVA at about 15 kV and a frequency of about 1 Hz through a 3/16" gap between 1/4" tungsten electrodes, produces thermal neutrons with less than 1 MeV." [16] (p. 412).

This is a decidedly practical result considering the usual bulky, hazardous and costly mechanisms of spallation sources and research reactors currently used in the production of thermal neutrons.

We see in this series of tests [16] the expected positive correlation between arc energy, gas pressure and neutron synthesis rates such that at 100 psi hydrogen gas pressure and arc strength of 50 kVA radiation of such potency is produced so as to necessitate the closure of the lab and preclude even the proper collection of data.

Recent tests reported privately to us by Santilli clearly state that a nonlinear relation exists between arc pressure, gas pressure and neutron production [17]. From one such correspondence:

". . . neutrons are not synthesized in appreciable numbers of CPS for arc voltage less than 3 *kV* and energy less than 3 *mJ* and that, beyond the threshold values, the number of neutron CPS increases non-linearly with the increase of the hydrogen pressure, the arc voltage and the delivered energy." [17] (p. 3).

It may be concluded that*: Only such energies as those used in the work of Santilli which exceed threshold energy values as specified can directly produce neutrons.* The mechanism of neutroid interactive substance-specific nuclear transmutation involved in delayed neutron synthesis at low arc energies will be defined shortly. In our consultations Santilli has strictly specified that a low energy continuous arc can only produce neutroids (see below), and threshold minimum energies expressed in a pulsing arc (fig. 4) are required for the most efficient direct neutron production.

Clearly, the arc energy was below threshold values in the experiments of Sternglass and Borghi to have accounted for the direct production of neutrons and so we propose, only *neutroids* would have been synthesized from the $35kV$ $30mA$ and $500V$ $10mA$ currents used, hence those *neutroids were then only subsequently transformed into neutrons.* Next, it will be demonstrated how this proposed delayed transformation occurs.

III. THEORETICAL ANALYSIS.

History:
In order to address and repair the limitations of quantum theory and relativity so as to allow new solutions to be derived, a mathematical covering of existing theory was required. The new model which has achieved this, that of Santilli's Hadronic Mechanics, is based on new mathematics called "Iso-mathematics" which has been extended to include several new methods of calculation [18,19,20,21,22,23,24].

To condense briefly from references [18,19,20,21,22,23,24]:

Isomathematics is derived through an isotopic lifting of the conventional associative product between generic quantities into an iso-product. In this way, the mathematics and differential calculus of Newton-Leibniz might be

reformulated so as to find new answers and solutions to old problems. Lie's theory has been augmented to articulate non-linear, non-local and non-Hamiltonian systems (meaning, variationally nonself-adjoint systems not representable with a Hamiltonian). Fundamental time evolution invariance was accounted for in Santilli's Iso-Differential calculus. A summary of these ideas is available here: [19,23,24]. The Schrodinger-Santilli isoequations underlying hadronic mechanics and the Heisenberg-Santilli isoequations constituting a *completion* of existing quantum theory have been created. [22] (pp. 64-65).

Experimentally demonstrated inconsistencies articulated in this paper regarding orthodox quantum mechanics and relativity have been addressed and new theoretical solutions which fit experimental results have been offered by way of the successful *covering* of existing theory. The resulting model includes relativistic and nonrelativistic treatment of *all characteristics* of the neutron in its synthesis from a proton and an electron using isomathematics and related isomechanics which allow the representation of the proton with its actual extended shape, as can be seen here:[14*a*,15,16,19,20,25,26,27,28,29].

Further theoretical explanation may be found below.

Applied theory:

Quantum mechanics is unable to account for these experimental results. Further explanation will follow; note initially that:

$$Ep = 938.272\ \text{MeV},\ \ Ee = 0.511\ \text{MeV},\ \ En = 939.565\ \text{MeV}, \tag{3a}$$

$$En - (Ep + Ee) = 0.782\ \text{MeV} > 0, \tag{3b}$$

indicating the rest energy of the neutron is 0.782 MeV greater than the combined rest energies of the proton and electron, demonstrating both "positive binding energy" and "mass excess" which are both *disallowed* by quantum mechanics.

The Neutroid:
Don Borghi and his scientific associates coined the name "neutroid" (symbolized

here as $\tilde{n}$). The neutroid was proposed as an intermediate particle mutation preceding synthesis of actual neutrons. Neutroids have also been experimentally created by Santilli. Santilli defines the proposed neutroid as a (spin zero) particle having the values (in standard nuclear units: A = total number of nucleons; Z = number of protons; (N = number of neutrons); J the total angular momentum; with *amu.* = mass),

$$A = 1, Z = 0, J = 0, \text{m} = 1.008amu.$$

Santilli then writes:

$$p^{+}{}_{\uparrow} + e^{-}{}_{\downarrow} \rightarrow \tilde{n}(1, 0, 0, 1.008) \tag{4}$$

where $J = 0$ avoids a spin anomaly in the synthesis [29].

In order to fully articulate the proposed formalism and mechanics of neutroid to neutron transformation within a process of substance-specific nuclear transmutation yielding experimentally demonstrated delayed neutron synthesis, we must return to the idea of the neutrino and offer a new piece of theory.

The Santilli Aetherino:

The currently accepted theory of weak interactions has been applied in a model of inverse beta decay with proposed collective electron effects in order to explain the creation of neutrons from hydrogen catalyzed through nuclear reactions on metallic hydride surfaces [12, 30]. However, the high probability of inelastic scattering in these low energy experiments has not been addressed to the satisfaction of the discipline within those explanations offered in this model [12].

A causal model and specific explanation of neutron synthesis detailing internal hadronic structure is available in Hadronic Mechanics [19], Hadronic Chemistry [31] and the theory of the Santilli Aetherino [32]. A new mathematical construct (with flexible -/+ signs) along with experimental demonstration the existence of neutroids and the synthesis of the neutron with over 340 tests will soon be published as: *Experimental confirmation of the synthesis of neutrons and neutroids from a hydrogen gas*: [33].

In standard theory neutron synthesis as here discussed requires emission of a neutrino, or absorption of an antineutrino:

$$p^+ + e^- \rightarrow n + \nu, \tag{5a}$$

or

$$p^+ + e^- + \bar{\nu} \rightarrow n. \tag{5b}$$

Logically, this is assertion is necessarily revealed as flawed:

1. A positive binding energy of 0.782 MeV is indicated to account for the rest energy difference between the constituent components of the neutron, the electron and the proton, and the neutron itself. However the Schrödinger equation does not admit such positive binding energies and can not account for the bound state of the electron within the hyper-dense medium of the proton.

2. Experiments plainly demonstrate a positive binding energy. However in classical anti-matter theory the antineutrino is ascribed negative energy, contrary to experimentally derived data.

3. Antineutrinos have a *null cross section* for electron and proton interactions, contrary to experimental results.

4. Paradoxical results seem to indicate neutrino scattering effects implying some "particle" mass, yet no particle is detected. Such "particle scattering" sans particle implies another solution: a longitudinal impulse moving through a substantial surrounding energy density interacting with targets: *the Aetherino* (symbolized as: "*a*") [32].

The Aetherino carries mass and charge zero, spin 1/2 and 0.78 energy according to the synthesis $p^+ + a + e^- \rightarrow n$.

A. Neutron from substance-specific neutroid absorption and aetherino:

We may now directly approach the delayed synthesis of neutrons demonstrated in

low energy experiments by way of articulating the formalism used to define Aetherino/Neutroid interactivity within the context of detector and experimental substance-specific nuclear transmutation and then applying that formalism to the specific compounds actually used in the experiments and detectors [15, 29]. The basic equation is written as:

$$\tilde{n}(1,0,0,1.008)+a \rightarrow n(1,0,1/2,1.008) \qquad (6)$$

The basic component interaction is given by:

$$N(Z,A,J)+\tilde{n}(0,\,1,\,0)+a(0,\,0,\,1/2) \rightarrow \qquad (7)$$

where N is a nuclide. The probable transformation of the neutroid is that of a neutron given by,

$$\tilde{n}+a \rightarrow n, \qquad (8)$$

that of the predicted form,

$$N(Z,A,J)+\tilde{n}(0,\,1,\,0)+a(0,\,0,\,1/2) \rightarrow N'(Z,A+1,J+1/2)\,. \qquad (9)$$

In Don Borghi's tests, gold appears to act as a neutron source through the absorption and subsequent transformation of neutroids via the calculation:

$$Au(79,197,3/2)+\tilde{n}(0,\,1,\,0)+a(0,\,0,\,1/2) \qquad (10)$$

$$\rightarrow Au(79,198,2)+a(0,\,0,\,1/2)$$

$$\rightarrow Hg(80,\,198,\,0)+\beta^{-}(-1,\,0,\,1/2)+\gamma(0,\,0,\,1)$$

The silver in Sternglass' experiments absorbed neutroids to produce neutrons as given by:

$$Ag(47,\,107,\,1/2)+\tilde{n}(0,\,1,\,0)+\,a(0,0,\,1/2) \qquad (11a)$$

$$\rightarrow Ag(47,\,108,\,1)+\,a(0,0,\,1/2) \rightarrow$$

$$\rightarrow Cd(48, 108, 0)[\textit{stable isotope}] + e^{-}(-1, 0, 1/2)$$

$$Ag(47, 109, 1/2) + \tilde{n}(0, 1, 0) + a(0, 0, 1/2) \qquad (11b)$$

$$\rightarrow Ag(47, 110, 1) + a(0, 0, 1/2) \rightarrow$$

$$\rightarrow Cd(48, 110, 0)[\textit{stable isotope}] + e^{-}(-1, 0, 1/2)$$

The *Li*-activated detectors in Santilli's experiment function as mediators of aetherino and neutroid interactivity yielding neutrons by:

$$Li(3, 7, 3/2) + \tilde{n}(0, 1, 0) + a(0, 0, 1/2) \qquad (12)$$

$$\rightarrow Li(3, 8, 2)$$

$$\rightarrow 2\,\mathrm{He}(2, 4, 0) + 2\,\gamma(0, 0, 1)$$

We may deduce: *the substances used for neutron detection are themselves the neutron source by way of neutroid absorption and subsequent nuclear transmutation. Li based detectors that can register thermal neutrons are best for this experimental work.* New mathematics and theory will soon be available here: [33].

IV. THE ROLE OF PHYSICAL THEORY

Physical theory explains experimental and observational results.

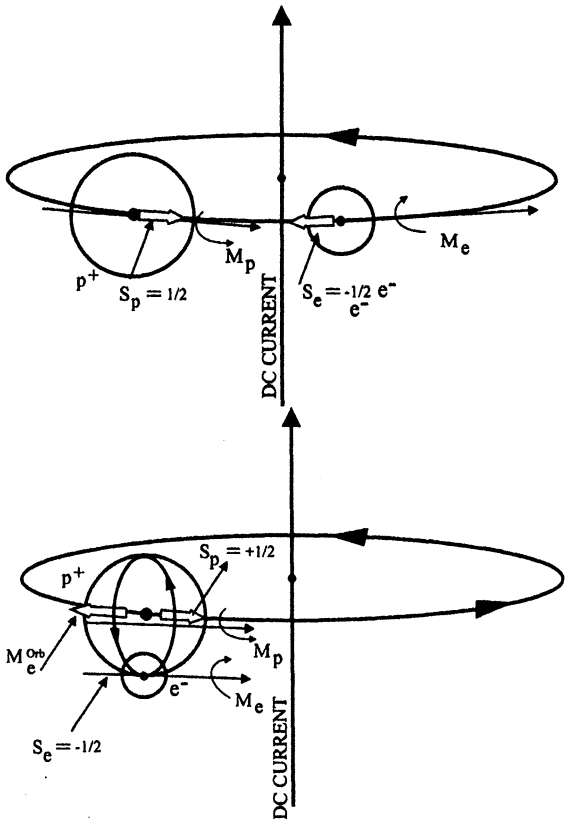

FIG. 5a. top FIG. 5b. below

A schematic view of the tangential alignment of protons and electrons along the tangent to a magnetic force line (Fig. 5a), and a view of the compression of the electron against the proton caused by opposing electric and magnetic polarities (Fig. 5b) [16] (Santilli, 2014) (Used with permission of Ruggero Santilli/Journal of Computational Methods in Sciences and Engineering).

Hadronic mechanics offers a clear causal mechanism to explain these results. The electrons and protons constituting the hydrogen gas become ionized in the arc, and by way of its tangential relation to the magnetic force lines the electron breaches the proton's hadronic horizon via opposing magnetic and electric polarities, leading to singlet coupling. The mass difference of the order of 2000 times between the heavy proton and the light electron ensure that the proton is not mutated, while the electron demonstrates constrained angular momentum orbiting

then within the proton's hadronic sphere. In this way, a stable singlet coupled particle with the proper spin is created: the neutron.

Hadronic structure is defined within Hadronic Mechanics and Chemistry as a contact type interaction characterized by full emergence of one wave-packet within the other. The dynamic tangential relations between the proton and electron ionized gas constituents mediated by DC magnetic force lines so as to breach the hadronic proton horizon and compress the electron within the proton and bind them together in singlet coupling as a neutron, offer us a specific physical mechanism to explain observed inelastic scattering probabilities:

The electron collapses into the proton from attractive Coulomb forces due to opposing charges and magnetic moments [14*a*].

Further detailed theory and mathematical explanation may be found here: [19,29,31,32].

See
[14*a*,15,16] for further examples of neutron and neutroid syntheses under various experimental conditions and constraints.

Possible implications for quantum theory

The parsimonious interpretation of the empirically derived internal neutron structure is that of an electron bound within a proton. If this is so, axiomatic adjustments to the current Hadronic and Quantum paradigms are logically indicated:

1. The Schrödinger equation fails to produce correct physical solutions in the case of the experimentally indicated 0.782 MeV *positive binding energy* over the rest energies of the proton and electron which is required to synthesize neutrons.

2. Quantum mechanics forbids the synthesis of the spin 1/2 neutron from the bound state of the spin 1/2 proton and spin 1/2 electron.

3. The electron being bound into the proton for the 15 *m* life of an isolated

neutron is not permitted in quantum mechanics.

4. The magnetic moments of the proton and electron are insufficient to account for the magnetic moment of the neutron according to quantum theory.

5. The uncertainty principle does not allow the electron to be bound permanently within the proton in stable nuclei such as the deuteron.

6. The interpretation of internal neutron structure which is most parsimonious, is that of an electron bound within a proton, not that of quarks. A simpler neutron structure has been articulated. The undetectable free quark is no longer required.

7. The model of Hadronic Mechanics and Chemistry implies new hadronic fuels, possible stimulated nuclear decay and rapid safe elimination of radioactive nuclear waste (see below) [31].

8. The neutron can be re-conceptualized as the hadronic bound state of the hydrogen atom with the electron orbiting within a proton (see figure 6 below). Ergo: the ordinary energy levels of the hydrogen atom may be rightly conceptualized as the excited states of the neutron.

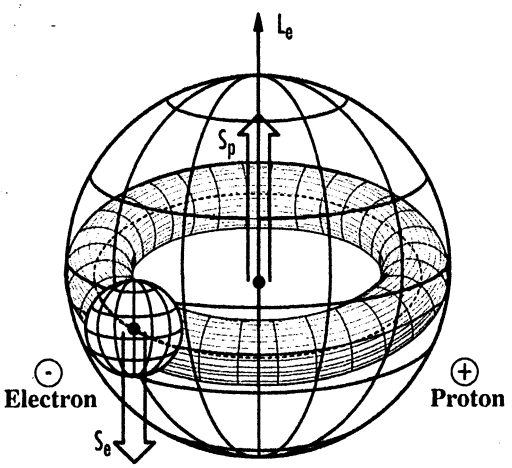

FIG. 6. Image of the hydrogen atom's electron orbiting within the proton forming a neutron in

singlet coupling. The neutron is the hadronic bound state of the hydrogen atom. Used with Permission of Ruggero Santilli.

V. PRACTICAL BENEFITS OF PARADIGM SHIFT

Should physics choose to adjust the paradigm to fit the experimental results afforded by this simple experiment rather than suppress those results, the potential benefits to mankind and the sciences are extensive in their scope.

An alternative method for disposal of high-level radioactive waste.

An alternative method for disposing of high-level radioactive waste has been proposed by Santilli. It is a form of neutralisation but does not use the conventional methods currently being researched. Indeed, classical formulations of quantum chemistry and nuclear models do not even permit the practical method proposed. This new method arises from a number of discrepancies between the theoretical and measured values using the current formulation of quantum mechanics. Conventionally, the probability for beta-decay of a neutron into a proton, electron and neutrino is very low for radioactive elements on a nuclear timescale; for stable isotopes, the lifetime of neutrons is effectively infinite. Hadronic mechanics predicts that such a reaction may be stimulated within the nuclei of radioactive materials.

In essence, a radioactive nucleus is in an excited energy state and is attempting to return to its ground state energy. Under normal circumstances, this is achieved by spontaneous fission or radioactive emission; the time taken to decay being dependent on how much excess energy the nucleus has. This can vary between

10^{-31} seconds and millions of years. An excited nucleus can return to its ground state through emission of a photon (gamma emission), an electron (beta emission), or by spontaneous fission, where alpha emission is assumed to be a form of fission. The latter two processes cause a change in the nature of the parent nucleus, altering its nuclear properties. The energy value of the excited state determines the method by which the nucleus returns to its ground state. If the decay process involves the emission of a beta particle, it may be extrapolated that

a neutron will have to decay to achieve this.

From the theoretical calculations, it is hypothesised that this decay can be stimulated by bombarding the nucleus with so-called 'resonant' photons with an energy of 1.294 Mev [31]. Under normal circumstances the probability of this interaction is extremely low. However, Santilli claims that there is a large resonance peak in the reaction cross-section (that is, the probability of the said interaction occurring) for incident photons with an energy of 1.294 Mev. [1]

If this interaction is found to be true, its application for the disposal of radioactive waste is profound. Photons with the correct resonance energy can be produced easily within a piece of equipment of small volume, such that the neutraliser could be built on the same site as the parent reactor itself. Effectively, it would allow all radioactive waste to be fissioned until all the isotopes form stable nuclei. However, a point to note is that, taking a typical sample of waste, the resultant treated material would not be radioactively dangerous but chemically could be a totally unknown concoction of elements and compounds, which may well contain high levels of toxins. Another point to note is that stimulated fission would release a considerable amount of heat energy from the fuel, and so some sort of effective coolant would be required. However, since this heat energy could be used to produce even more power, there seems no reason in principle to suppose that what might be termed a secondary 'waste reactor' could not be built.

To continue quantitative scientific studies of the proposed new method for the disposal of nuclear waste essentially requires a few basic experiments to be

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1. It is also feasible, though not stated, that the simple existence of an excited nucleus makes it open to interaction with resonant photons, regardless of the means of decay ultimately used to return to its ground state energy. Once a neutron is converted into a proton plus reaction products, a number of possibilities could occur. Firstly, the new nucleus could be a stable isotope, in which case further interactions with the resonant photons would be unlikely and the waste would have been effectively neutralized. Secondly, the new isotope could form a new neutron deficient nucleus and one of the following could then occur: the nucleus undergoes spontaneous fission, forming two new nuclei and possibly a number of neutrons, which could interact with other fissile elements in the fuel and generate excess heat; the neutron deficient nucleus could form a new excited energy state which can simply be categorized as another target radioactive nucleus for the resonant photons.

performed. All should be of reasonable cost and are certainly realisable with present-day technology. It seems sensible to perform these experiments to decide whether or not the claims are valid. If they are, the rewards would be tremendous; if not, little would have been lost.

A. Hadronic fuels:

From the very beginning, one of the main driving forces behind Ruggero Santilli's hadronic science has been an urgent desire to help find new clean forms of energy for the benefit of all. To this end, hadronic mechanics has been developed and it is found that all energies predicted are suitable for the clean production of electricity and so may be used in the production of fuels acceptable in a so-called green economy. These new energies are found to be of three types; one at each of the particle, nuclear and molecular levels. These are all discussed in detail in the book on hadronic chemistry [31], although that volume does really concentrate on molecular aspects. However, the vitally important point to remember at all times is that the new proposed hadronic mechanics agrees with conventional theories everywhere except at short distances of the order of 10^{-13}cm. It is also important to remember that, at these short distances, many effects are non-potential ones and so may not be examined via the use of a Hamiltonian. These new effects are extremely short range and exhibit a number of unusual features:

(i) the non-hamiltonian interactions due to the deep mutual overlapping of the particle wavepackets in singlet coupling are attractive and are so attractive as to overcome repulsive Coulomb interactions,

(ii) they occur without any binding energy,

(iii)these new interactions imply a mutation of the intrinsic characteristics of particles, characterised by irreducible representations of the Poincaré-Santilli isosymmetry. e.g. a deformation of the charge distribution of protons and neutrons is representable by hadronic mechanics and allows an exact representation of nuclear magnetic moments.

The attractive nature of these new interactions combined with their lack of energy exchange and the possible alteration of the intrinsic character of particles allow for truly new clean energies. It remains to consider briefly these three types of new energy as alluded to earlier;

(1) Firstly consider that occurring at the elementary particle level.

It seems that the neutron harbours a huge reservoir of clean energy which could be.
made available to mankind. It is a naturally unstable particle with spontaneous decay

$$n \rightarrow p^+ + e^- + \bar{\nu}, \tag{13}$$

which releases electrons with huge kinetic energies up to 0.8MeV. Here, and later, the traditional notation incorporating the symbols for anti-neutrino and neutrino are used.

The capture of these electrons via a conducting screen provides a dual source of energy called hadronic energy. The first source is due to the creation of an electric potential difference, while the second is due to the creation of a large quantity of heat. This source is clean because no dangerous radiation is emitted and there is no harmful waste.

As is explained in detail in the book on Hadronic Chemistry [31], this so-called hadronic energy is based on three predictions:

(a) A peripheral neutron belonging to a group of light, natural, stable elements $N(A, Z)$, called hadronic fuels, may be stimulated to decay via a flux of photons γ with a resonating frequency of 1.294MeV,

$$\gamma + n \rightarrow p^+ + e^- + \bar{\nu}; \tag{14}$$

(b) The resulting nuclei $N(A, Z+1)$ are naturally unstable with spontaneous beta decay

$$\gamma + N(A,Z) \rightarrow N(A,Z+1) + e_1^- + \bar{\nu}_1 \rightarrow N(A,Z+2) + e_2^- + \bar{\nu}_1 + \bar{\nu}_2; \tag{15}$$

(c) The final nuclei $N(A, Z+2)$ of the class of hadronic fuels are light, natural, stable elements and so, there is no deposit of harmful waste material.

Examples of these so-called hadronic fuels are $Z_n(70, 30)$ and $M_0(100, 42)$. It should be noted also that the energy of the original resonating photon is not lost but remains available in the final usable energy. Also, for each resonating photon

there are two electrons and related kinetic energy produced. Again, in essence, the suggested process transforms the original nuclei into nuclei having smaller mass while producing large amounts of energy - large enough in fact to ensure a positive energy output after allowing for that needed to produce the original resonating photons. Obviously, hadronic energy is highly acceptable environmentally and it would seem that the suggested process readily delivers large amounts of usable energy. However, the entire theoretical discussion lies outside the realms of traditional theoretical physics, indicating a process which is impossible for traditional quantum mechanics. As will be noted again later, it does appear that this is what provides the most vociferous denunciation of this mentioned theory and the implied benefits for mankind if, in fact, the idea works. It does seem, though, to be a process worth evaluating independently both theoretically and experimentally since it could prove extremely beneficial for mankind if it works as expected.

(2) New Clean Energies occurring at the Nuclear Level.

As mentioned already, one of the biggest obstacles facing these new proposals is the firmly established position of quantum mechanics within scientific circles. Orthodox quantum mechanics simply doesn't allow for some of these developments; for example, it doesn't even allow the possibility of low energy stimulated nuclear transmutations but, even if such processes are admitted, it is claimed such are accompanied by the emission of harmful neutrons. Experimental verification of stimulated nuclear transmutations at low energy without the emission of neutrons would indicate direct support for this new theory which, in a very real sense, simply extends, or covers, existing quantum mechanical theory to include physical situations not addressed by that existing theory. However, in the present context, the crucial point is that the new theory predicts a totally new model for the structure of nuclei. In this new model, hadronic mechanics, they are reduced to being composed of electrons and protons but recovering the conventional structure in terms of protons and neutrons in first approximation. These new models are, as mentioned previously, a consequence of neutron model as a hadronic bound state of a proton and an electron as originally conceived by Rutherford. It follows that the new clean energies of classes 1 and 2 are very deeply interconnected, to the extent that experimental evidence of one is experimental evidence of the other.

Three types of new clean energies emerge in this class but possibly the first is the most obvious:

(a) This first source reignites thoughts about electron capture; that is, the spontaneous capture of electrons by certain nuclei under normal conditions on Earth. In truth, such electron capture implies the synthesis of neutrons from protons and electrons, leading to low energy transmutations of the form

$$N(A,Z) + e^- \rightarrow N(A,Z-1) + \nu. \tag{16}$$

This reaction is spontaneous but hadronic mechanics has indicated how such transmutations may be stimulated with a release of energy:

$$N(A,Z) + e^- + TR \rightarrow N(A,Z-1) + \text{heat}, \tag{17}$$

(b) A second group of energies of this second type may be identified by noting that the Earth's core is still so hot, after billions of years, that it must possess an internal source of heat which could well be due to nuclear transmutations such as envisaged above. It appears that observations, conformed by hadronic mechanics, indicate that such nuclear transmutations may well be reproducible here on Earth.

(c) A third group utilises the fact that, millions of years ago, the earth's atmosphere might have been composed of only 40% nitrogen. It is thought that the ensuing doubling of nitrogen content might well be due to nitrogen being synthesized in the atmosphere from other natural elements via a low energy nuclear process without the emission of harmful radiation. This is a process permitted by hadronic mechanics but not by conventional quantum mechanics.

It seems quite possible that the trigger required to provoke this process is simply lightning. Also, the most plausible candidates as the natural elements to be in these processes are carbon and deuterium which occurs in small amounts in ordinary water. The stimulated synthesis of nitrogen predicted by hadronic mechanics would then follow

$$TR + {}_1H^2 + {}_6C^{12} \rightarrow {}_7N^{14} + \text{heat}, \tag{18}$$

where the trigger in this case is lightning together with related events such as extreme magnetic fields. The low rate of such synthesis may be attributed to the low concentration of heavy water in our atmosphere. It should be noted that the energy output associated is impressive, [31]

As an interesting aside, it might be noted that the instantaneous availability of these large quantities of energy in this process provides an obvious explanation for thunder.

(3) New Clean Energies occurring at the Molecular Level.

In this class, the idea is to tap the energy within molecules; for example, via the transition from given molecules to structures at lower energy with practical use being made of the energy difference. These transitions would be utilised in hadronic reactors of molecular type, also called PlasmaArcFlow reactors, which are, incidentally, already in industrial production. More details of this category are readily available. [31]

It should be realised that the hadronic reactors of each of the three types considered are based on the same principle – that of stimulating the decay of considered bound states via resonating effects acting on the nonpotential component of binding forces. This constitutes a totally different approach as compared with conventional approaches utilising traditional quantum mechanics. The main physical principles behind each of the three classes discussed are identical. Hence, the experimental verification of one class gives immediate support for the existence of the other two classes. It is to be hoped that independent attempts at verification will be forthcoming soon because, if these classes do exist – and the present existence of operating PlasmaArcFlow reactors would appear to suggest that such attempted verification would be successful – the World's energy problems could be a thing of the past.

VI. CONCLUSION

The purpose of physical scientific theory is to explain physical systems as revealed in observation and experimental results. Theory must not refute facts but instead be able to account for them. Many experiments using various designs have now synthesized neutroids and neutrons from an arc of current in hydrogen gas, [12,14,14*a*,15,16,17] revealing the neutron in its internal hadronic structure

as being that far more more parsimonious interpretation of an electron within a proton as first proposed by Rutherford, not that of quarks [32]. We propose that contact type interactions of full wave-packet penetration at distances of 10^{-13} cm or less characterize hadronic structure as is the case with the neutron, which is defined and properly described in the model of Hadronic Mechanics and Chemistry [20, 31]. Direct neutron production from an arc of current in hydrogen gas requires a minimum arc voltage of 3 *kV* and energy of 3 *mJ*, or only neutroids will be produced which may potentially by way of substance-specific absorption and subsequent nuclear transmutation within particular materials then become neutrons. These specifics of hadronic and neutron structure as well as neutroid to neutron transformations are fully defined within the theoretical context of Hadronic Mechanics and Chemistry [20,31] permitting new approaches to the production of energy, and the clean up of nuclear waste. *Within the province of this one simple experiment and its variants, the hadronic paradigm itself may be reassessed.*

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MAJORANA, THE NEUTRON, AND THE NEUTRINO: SOME ELEMENTARY HISTORICAL MEMORIES*

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Abstract

At the kind request of the Editor of this Journal, and of TEC/TNRG (Usa), we recall in this article some elementary historical information about the role played by Ettore Majorana[1-17] with regard to the Neutron, and to the Neutrino. We often do explicitly insert direct quotations from the original written statements –in particular by Edoardo Amaldi[22-24]–, which in some cases, and for some topics, constitute the main available evidence.

Keywords: Ettore Majorana; Neutron; Neutrinos; Enrico Fermi; Edoardo Amaldi; Majorana spinors; Majorana algebras; Majorana fermions; Fred Wilczek; History of XX century physics; Reply to unjustified rumors

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1 Introduction

At the kind request of the Editor of this Journal, and of TEC/TNRG(Usa), we wish to recall some historical elementary information about the role played by Ettore Majorana[1-17] with regard to the Neutron, and the Neutrinos. Often, we shall explicitly insert direct quotations from the original written statements –in particular by Edoardo Amaldi[22-24]–, which in some cases, and for some topics, constitute the main available evidence

Let us start with the Neutron.

2 THE NEUTRON

As soon as the news of the Joliot-Curie experiments[18] reached Rome at the very beginning of 1932, Majorana understood that they had discovered the "neutral proton" without realizing it. Thus, even before the official announcement of the discovery of the neutron, made just after by Chadwick[19], Majorana was able to explain the structure and the stability of atomic nuclei through protons and neutrons, preceding in this way also the pioneering work of D.Ivanenko[20]: as both E.Segré and E.Amaldi have recounted in detail. His colleagues remember that before Easter he had already concluded that protons and neutrons (indistinguishable with respect to the nuclear interaction) were bound by the "exchange forces" originating from the exchange of their spatial positions only (and not also of their spins, as Heisenberg will instead propose), so as to obtain the alpha particle (and not the deuteron) as saturated in respect of the binding energy. Only after that Heisenberg had published his own article on the same argument, Fermi was able to persuade Majorana to meet the famous colleague in Leipzig; and finally Heisenberg does convince Majorana to publish his results in the paper "Über die Kerntheorie"[21]. Majorana's paper on the stability of nuclei was immediately recognized by the scientific community –a rare event, as we know, for his writings– thanks to that timely "propaganda" done by Heisenberg himself.

The role of Majorana in connection with the Neutron was mentioned, e.g., in our book[1]; but it is based only on the testimonies by the Colleagues he had in the reasearch group leaded by Enrico Fermi at Rome: in particular, as we were saying, by Edoardo Amaldi[22-24] and by Emilio

Segré[25-26]. We therefore prefere to confine ourselves, here, to quote the original written statements, they constituting the main available evidence.

2.1 A first written account by E.Amaldi

A rather extensive account has been written by Amaldi in 1968 in Ref.[23]. We report it here, for historical reasons, even if in Italian (*adding our translation of it into English in* **Appendix A**). We shall report, in the following, a similar statement written by Amaldi in English, and appeared in 1984 in his Ref.[24].

<< Verso la fine di gennaio 1932 cominciarono ad arrivare i fascicoli dei *Comptes Rendus* contenenti le classiche note di F.Joliot e I.Curie sulla radiazione penetrante scoperta da Bothe e Becker. Nella prima di tali note veniva mostrato che la radiazione penetrante, emessa dal berillio sotto lazione delle particelle alfa emesse dal polonio, poteva trasferire ai protoni, presenti in straterelli di vari materiali idrogenati (come lacqua o il cellofan), energie cinetiche di circa cinque milioni di elettronvolt. Per interpretare tali osservazioni, i Joliot-Curie avevano in un primo tempo avanzato lipotesi che si trattasse di un fenomeno analogo alleffetto Compton Subito dopo, per, avevano suggerito che leffetto osservato fosse dovuto a un nuovo tipo di interazione fra raggi gamma e protoni, diversa da quella che interviene nelleffetto Compton.

Quando Ettore lesse queste note, disse, scuotendo la testa: Non hanno capito niente: "probabilmente si tratta di protoni di rinculo prodotti da una particella neutra pesante". Pochi giorni dopo giunse a Roma il fascicolo di *Nature* contenente la Lettera allEditore presentata da J.Chadwick il 17 febbraio 1932 e in cui veniva dimostrata lesistenza del neutrone sulla base di una classica serie di esperienze Subito dopo la scoperta di Chadwick, vari autori compresero che i neutroni dovevano essere uno dei costituenti dei nuclei e cominciarono a proporre vari modelli in cui entravano a far parte particelle alfa, elettroni e neutroni. Il primo a pubblicare che il nucleo è costituito soltanto di protoni e neutroni è stato probabilmente D.D.Ivanenko Ma certo che, prima di Pasqua di quello stesso anno, Ettore Majorana aveva cercato di fare la teoria dei nuclei leggeri ammettendo che i protoni e i neutroni (o "protoni neutri" come egli diceva allora) ne fossero i soli costituenti e che i primi interagissero con i secondi con forze di scambio delle sole coordinate spaziali (e non degli spin), se si voleva far sì che il sistema saturato rispetto allenergia di legame fosse la particella alfa e non il deutone.

Aveva parlato di questo abbozzo di teoria agli amici dellIstituto e Fermi, che ne aveva subito riconosciuto linteresse, gli aveva consigliato di pubblicare al pi

presto i suoi risultati, anche se parziali. Ma Ettore non ne volle sapere perché giudicava il suo lavoro incompleto. Allora Fermi, che era stato invitato a partecipare alla Conferenza di Fisica che doveva avere luogo nel luglio di quellanno a Parigi, nel quadro più ampio della Quinta Conferenza Internazionale sullElettricità, e che aveva scelto come argomento da trattare le proprietà del nucleo atomico, chiese a Majorana lautorizzazione di accennare alle sue idee sulle forze nucleari. Majorana rispose a Fermi che gli proibiva di parlarne o che, se ne voleva proprio parlare, facesse pure ma, in quel caso, dicesse che si trattava di idee di un noto professore di elettrotecnica, il quale fra laltro doveva essere presente alla Conferenza di Parigi, e che egli, Majorana, considerava come un esempio vivente di come non si dovesse fare la ricerca scientifica. Fu così che il 7 luglio Fermi tenne a Parigi il suo rapporto su "Lo stato attuale della fisica del nucleo atomico" senza accennare a quel tipo di forze che in seguito furono denominate "forze di Majorana" e che in sostanza erano già state concepite, sia pure in forma rozza, vari mesi prima.

Nel fascicolo della *Zeitschrift fuer Physik* datato 19 luglio 1932 apparve il primo lavoro di Heisenberg sulle forze "di scambio alla Heisenberg", ossia forze che coinvolgono lo scambio delle coordinate sia spaziali che di spin. Questo lavoro suscit molta impressione nel mondo scientifico: era il primo tentativo di una teoria del nucleo che, per quanto incompleta e imperfetta, permetteva di superare alcune delle difficolt di principio che fino ad allora erano sembrate insormontabili. NellIstituto di Fisica dellUniversit di Roma tutti erano oltremodo interessati e pieni di ammirazione per i risultati di Heisenberg, ma al tempo stesso dispiaciuti che Majorana non avesse non dico pubblicato, ma neanche voluto che Fermi parlasse delle sue idee in un congresso internazionale

Fermi si adoperò nuovamente perché Majorana pubblicasse qualche cosa, ma ogni suo sforzo e ogni sforzo di noi, suoi amici e colleghi, fu vano. Ettore rispondeva che Heisenberg aveva ormai detto tutto quello che si poteva dire e che, anzi, aveva detto probabilmente *anche troppo.* Alla fine però Fermi riuscì a convincerlo ad andare allestero, prima a Lipsia e poi a Copenaghen, e gli fece assegnare dal Consiglio Nazionale delle Ricerche una sovvenzione per tale viaggio che ebbe inizio alla fine di gennaio del 1933 e durò dal 19 gennaio al 5 agosto (1933), a parte una interruzione dal 12 aprile al 5 maggio. >>

For our translation in English of this historical account, see (as we said above) our *Appendix A.*

2.2 From the Amaldi's 1984 *Physics Reports* on Neutrons and nuclear fission.

Let us now quote a different account by E.Amaldi, this time[24] in English, appeared in 1984 in his Ref.[24]

<< ...it appears in order to add a few remarks of historical nature about the contribution of Ettore Majorana to the understanding of nuclear forces. When the issue of the "Comptes Rendus" containing the first note by F.Joliot and I.Curie[18] on the penetrating radiation discovered by Bothe and Becker arrived at the library of the Institute of Physics of the University of Rome, Ettore read it and, shaking his head said more or less: "They haven't understood a thing. They probably are observing the recoil protons produced by a heavy neutral particle". A few days later we got in Rome the issue of "Nature" containing the Letter to the Editor from Chadwick in which he demonstrated the existence of the neutron[19]. In order to understand how Ettore could guess this discovery, which was suggested but certainly not demonstrated by the results of Joliot and Curie, it should be remembered that he was familiar, through a paper published a few years earlier by Giovanni Gentile junior, with the nuclear model proposed in 1927 by Lord Rutherford, already mentioned by us above. Gentile had shown the inconsistency of that model. The idea, however, that there might exist in nature neutral particles of subatomic dimensions had, as it were, remained in the air, also in Rome. Neither I, nor his other friends, recently questioned, remember whether Ettore Majorana came to the conclusion that the nucleus consists solely of protons and neutrons independently from other authors. What is certain is that before Easter 1932 he worked out a theory of light nuclei, assuming that they consisted solely of protons and neutrons (or 'neutral protons', as he then said) and that the former interacted with the latter through exchange forces. He also reached the conclusion that these exchange forces must act only on the space coordinates (and not on the spin) if one wanted the alpha particle, and not the deuteron, to be the system saturated with respect to the binding energy. He talked about this outline of a theory to his friends at the Institute, and Fermi, who had at once realized its interest, advised him to publish his results as soon as possible, even though they were partial. However, Ettore would not want to know about that, because he considered his work to be incomplete. Thereupon, Fermi, who had been invited to the physics conference which was to

take place in July of that year in Paris in the wider framework of the Fifth International Conference on Electricity, and who had chosen as his subject the properties of the atomic nucleus, asked Majorana for permission to mention his ideas on nuclear forces. Majorana forbade Fermi to mention them, but added that if he really must, he should say they were the ideas of a well-known professor of electrical engineering who, incidentally, was to be present at the Paris conference and whom Majorana considered to be a living example of how not to carry out scientific research. Thus, on July 7, Fermi presented his report in Paris on "The Present State of the Physics of the Atomic Nucleus" without mentioning the type of force which was subsequently called 'Majorana exchange force' and which had actually been thought of, although in a crude form, some months earlier. The issue of the "Zeitschrif fuer Physik" dated July 19, 1932 contained Heisenberg's first paper on 'Heisenberg exchange forces', namely forces involving the exchange of both the space and spin coordinates.

<< Fermi again tried to persuade Majorana to publish something, but all his efforts and those of his friends and colleagues were in vain. Ettore replied that Heisenberg had now said all there was to be said and that, in fact, he had probably even said too much. *Finally, Fermi succeeded in persuading Majorana to go abroad, first to Leipzig and then to Copenhagen, and obtained a grant from the National Research Council for his journey, which began at the end of January 1933 and lasted from Jan. 19 to Aug. 5 (1933), a part from an interruption the 12th of April to the 5th of May. Majorana's aversion to publishing or making known in any way his results, which appears from this episode, was part of his general attitude. >>*

<< During the period spent in Leipzig, Majorana became friendly with Heisenberg for whom he always had a great admiration and a feeling of friendship. It was Heisenberg who persuaded him without difficulty, by the sheer weight of his authority, to publish his paper on nuclear theory which appeared the same year[21] in the 'Zeitschrift fuer Physik'. >>

Before going on, let us present a portrait of Ettore Majorana in Fig.1.

2.3 On the first attempts to a theory of the Nucleus

From the same 1984 paper, published by E.Amaldi[23] in "Physics Reports", let us report for completeness' sake his history of **the theory of**

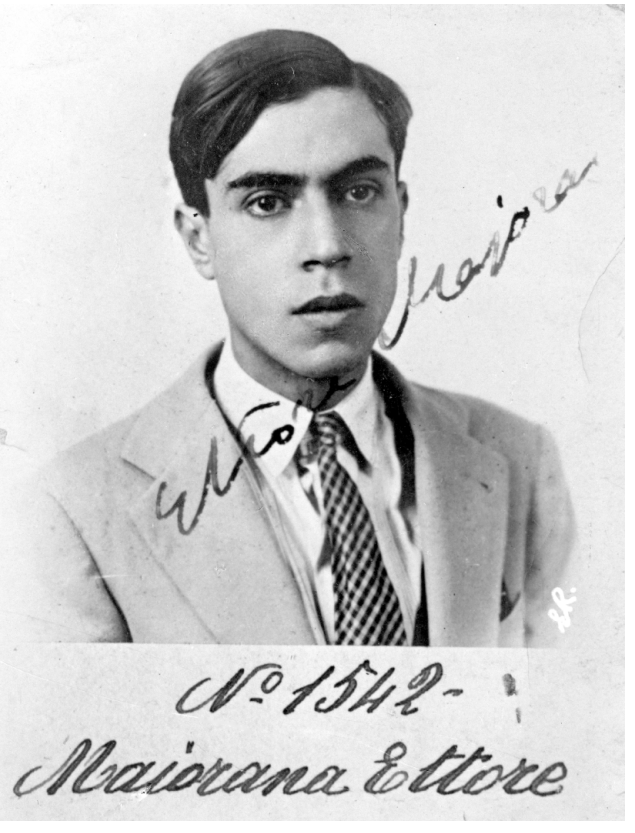


Figure 1: The best portrait of Ettore Majorana, when 23. Reproduction forbidden [copyright by M.Majorana & E.Recami].

the nucleus: Namely, his historical considerations on *the first attempts of a theory of nuclei composed of protons and neutrons only.*

<< Heisenberg, Majorana and Wigner were the first to appreciate fully the importance of the new model describing the nucleus as a system composed only of protons and neutrons. The formalism of non-relativistic quantum mechanics could be applied to it for trying to explain qualitatively, and in part quantitatively, a few nuclear properties. Such a programme clearly involved the introduction in the Schroedinger equation of a "potential" describing the new forces acting between the nuclear constituents. The choice of this potential was made by the three authors menti oned above, in different ways. Each of them had its grounds and merits and remained as a useful (or even necessary) ingredient of many successive developments. The nuclear forces we consider here were

the first example of one of the four fundamental interactions acting among subatomic particles, the strong interaction. A fascinating presentation of a number of historical aspects of these early stages of nuclear physics can be found in the Proceedings edited by R.H.Stuewer, in particular in the articles by Wigner and by Peierls. Everybody was ready to accept that new and very strong forces were required to hold the nucleus together, but very little was known about their behaviour, in particular about their dependence on the distance as well as on other variables. Two important properties, however, were known for a long time: (1) The nuclear forces do not extend to very large distances, beyond the nuclear radius. Any long-range nuclear force strong enough to keep the nuclei together would manifest itself through a modification of molecular behaviour. Hence the nuclear potential should have a "short-range" , i.e. decrease with the distance between two nuclear constituents faster than the $1/r$ Coulomb potential. (2) The binding energy of nuclei rises proportionally to the mass number A (i.e., the number of its constituents), as it happens, for example, for the energy of the intra-molecular forces of a drop of liquid. This property, known as saturation of the nuclear forces can be obtained by considering various possibilities about their nature, a few of which (actually the simplest) are the following:

(i) Exchange forces;

(ii) Repulsive forces at very short distances (i.e., a "repulsive core"),

(iii) Velocity dependent forces;

(iv) Many-body forces.

Only the first possibility was used at the beginning, while for rather weak reasons the others were considered only at successive times.

<< In his first paper, dated June 7, 1932, Heisenberg starts from a nucleus composed of protons and neutrons with the additional assumption that the neutron, like the proton, is a particle with spin 1/2, which follows Fermi's statistics.

He tries to define the nature of the forces between these particles. On the basis of the analogy with the case of the homopolar forces of chemistry, Heisenberg assumes that between neutrons and protons there is an exchange potential $J(r)$ due to an exchange of "negative charge" similar to that responsible for the binding of the molecular hydrogen ion (H_2^+). As a comment to this assumption, he writes (in German): "These exchanges can be made intuitive by means of the picture of an exchange of "electrons" without spin and that follow Bose statistics. It is, however, more correct to consider the exchange integral $J(r)$ as a fundamental property of the neutron-proton pair without trying to reduce it to electron movements". He also introduces a neutron-neutron attractive interaction $K(r)$ similar to the exchange potential that gives rise to the H_2 molecule, while for the proton-proton pairs he considers only the Coulomb repulsion. By

analogy with the molecular case he also assumes $J(r)$ to be considerably larger than $K(r)$. Thus Heisenberg's Hamiltonian of a nucleus, consisting of Z protons and N neutrons, turns out to be the sum of five terms originating from the kinetic energy of the particles, the neutron-proton exchange potential $J(r)$, the neutron-neutron exchange potential $K(r)$, the proton-proton Coulomb repulsion and the neutron-proton rest energy difference.

In writing his Hamiltonian, Heisenberg attributes to each particle, in addition to the usual space and spin coordinates, a fifth variable ρ^3 which takes the values +1 for neutrons and -1 for protons and treats it formally as the third component of "a spin" (later called isotopic spin) with components analogous to the 2 x 2 Pauli spin matrices but acting in a new space that "has nothing to do with ordinary space". This formalism was useful (but certainly not necessary) for writing interaction terms that transform a neutron into a proton or vice versa. Only starting from 1936, an increasing number of new phenomena which were gradually discovered and studied in sufficient detail, led to isotopic spin being accepted as a new physical quantity, whose conservation is a generally valid principle in the sense that it is respected in all processes involving strong interactions only. From a qualitative discussion of his Hamiltonian, Heisenberg deduces a number of interesting consequences. The largest terms in the Hamiltonian are the kinetic energy and the charge-exchange potential $J(r)$, both symmetric in neutrons and protons. Therefore, if only these two terms are taken into account, the nuclei with equal number of neutrons and protons are energetically favoured and thus should have the greatest stability. On the other hand the long range Coulomb repulsion between protons and the short range weak attraction $K(r)$ between neutrons both favour increasing number of neutrons for the stability of heavier nuclei, in agreement with observation. He then discusses the Schroedinger equation of the recently discovered deuteron, i.e. the neutron-proton system in its ground state. He finds that the corresponding eigenfunction is symmetric in the charge and space coordinates of the two particles which, because of the Pauli principle, should have opposite spin. This prediction is wrong, but at the time of Heisenberg's first paper the spin of the deuteron was not yet known. It was a consequence of Heisenberg's choice of the sign of $J(r)$ to be the same as for the hydrogen molecular ion and can be cured by changing it. What remains wrong with Heisenberg's forces, irrespective of the sign of $J(r)$, is that the deuteron is the saturated system and not the alpha particle, as it is suggested by the measured values of the mass defect of light nuclei. The rest of the paper is devoted to the discussion of the properties of intermediate and heavy nuclei, of their binding energy and beta and alpha instability. This leads him to describe, semi-qualitatively, the behaviour of the binding energy of the nuclei as a function of

Z and N, a subject to which he returns in his second paper, dated July 30, 1932, where he discusses in a form destined to be more or less final, the difference of energy between nuclei with Z and N both even, with Z or N odd, and with Z and N both odd. It is very interesting to see how he succeeded in arriving at conclusions which (although semi-quantitative) are substantially correct, in spite of the fact that at that time the beta processes with emission of positrons had not yet been observed. They were discovered by Joliot and Curie only at the beginning of 1934. In the same paper Heisenberg discusses two more problems: the large absorption and scattering of γ rays observed in those years by various authors, and the properties of the neutron. It was clearly shown that gamma rays of a few MeV energy are absorbed and scattered in matter, in considerable excess with respect to theoretical estimates based on the Klein-Nishina formula. The effect was generally assumed to be of nuclear origin and Heisenberg tried to explain it by considering, in addition to the changes of the movements of protons and neutrons inside the nucleus, due to the electric field of the incident radiation, also the "excitation of the negative charge (electron) bound in each neutron". Because of the small mass of the electron this second mechanism was found to give a contribution large enough for representing the experimental data, and thus provided, in Heisenberg's opinion, an argument in favour of the existence of an electron inside the neutron. In 1933, however, it was found that the "excess absorption" is due to pair production and the "excess scattering" to the annihilation of electron-positron pairs.

<< On the other hand if the neutron is regarded as a system composed of one electron and one proton so strongly bound as to have linear dimensions much smaller than the nucleus, one faces, in an aggravated form, the same conceptual difficulties met by any nuclear model with intra-nuclear electrons. Both the problem of the scattering of gamma rays by nuclei and that of the nature of the neutron are taken up and further investigated by Heisenberg in his third paper dated December 22, 1932. He puts forward two alternative hypotheses on the nature of the neutron: the first is that the neutron is an elementary particle without structure, as assumed by Perrin. However, in order to explain the beta decay of a heavy nucleus it would be necessary for the latter to contain electrons in addition to neutrons and protons. Thus, there arise difficulties, which cast doubts also on the second hypothesis of the structure of the neutron: the neutron consists of an electron and a proton and as such is likely to interact through exchange forces with the proton. The situation appeared to Heisenberg to be so serious as to prompt him to advance the hypothesis that quantum mechanics might be inadequate to describe the phenomena which take place on a nuclear scale. Today, we know that this is not true and that this difficulty, and others

which are not mentioned here, was to disappear with the hypothesis put forward by Yukawa in 1935, that the particles exchanged between any two nucleons, namely protons and neutrons, are not electrons but mesons, namely particles of integral spin (which are, therefore governed by Bose statistics) whose mass is at least 280 times greater than that of the electron. The experimental confirmation of this idea came by steps over a period of 12 years: 1935–1947. A large part of Heisenberg's third paper is devoted to extending the Thomas-Fermi[27] method to the case of the nucleus, assuming for this purpose a Hamiltonian which differs from that given in the first paper only in so far as, in addition to the exchange forces, there are also ordinary forces acting between protons and neutrons.

Heisenberg deduces the expression of the energy of the system in its lowest state, imposing as a condition that the probable value of the Hamiltonian be stationary with respect to arbitrary variations of the density of the particles. At first, the Hamiltonian was calculated by taking for the kinetic energy of the protons and neutrons, as in the Thomas-Fermi method[27], the expression valid for a totally degenerate Fermi gas not subjected to external fields, and a potential energy of the form described above. Under these conditions, however, it is not possible to avoid the collapse of the nucleus as a result of the fact that the nuclear forces tend to reduce to zero, or at least to an extremely small value, the distance between the two particles of each neutron-proton pair. In order to overcome this drawback Heisenberg had to introduce a cut-off in the potential energy at the shortest distances, a forerunner of what, at later times, was to be called a repulsive core.

<< Majorana's paper[21], dated Leipzig, March 3, 1933, appeared at this point. After re-examining the hypothesis of the Heisenberg model, Majorana reconsidered the difficulties relating to the structure of the neutron and reached the conclusion that in the current state of knowledge, the only thing to do was to try to establish the law of interaction between proton and neutron on the basis of criteria of simplicity only, but in such a way as to reproduce as correctly as possible the most general and characteristic properties of the nuclei. After having discussed some of these and having observed that the nucleus behaves like a piece of extensive and impenetrable "nuclear matter" , whose different parts interact only upon immediate contact, and having particularly stressed the fact that the experimental data clearly show a law of proportionality of both the binding energy and the volume with respect to the total number of nucleons present, Majorana introduces an exchange potential acting on the space coordinates alone, whose sign was such as to be attractive in states of even angular momentum. He justifies his choice by observing that by doing this, two

important results are obtained. The first is that both neutrons of the a particle exercise an attraction on each proton. The second is that in the approximation in which the Coulomb repulsion is neglected, the eigenfunction of the a particle is totally symmetric in the coordinates of the centres of mass of the four component particles, as it is reasonable to expect since it represents a complete shell. Turning from the a particle to heavier nuclei, the additional nucleons are forced, because of Pauli's principle, to enter into more excited states and since the exchange energy is high only in the case of particles in the same (or almost the same) orbital state, it is concluded that saturation of both the binding energy and the density is practically reached in the case of the a particles. The essential differences with respect to Heisenberg's scheme is that the exchange forces concern only the space coordinates and the sign of $J(r)$ used by Majorana is the opposite of that of Heisenberg. Under these conditions the symmetry properties of the eigenfunctions are such that it becomes possible to explain the saturation phenomena without introducing a cut-off of the potential energy. Incidentally, I should recall that in comparing his Hamiltonian to that of Heisenberg, Majorana states that he avoids the "inconvenient" formalism of the "ρ spin" by treating the neutron and the proton as different particles. After these qualitative considerations, Majorana writes the Hamiltonian as the sum of the kinetic energy of all the particles, of the Coulomb repulsion energy between all the proton pairs and of the energy due to the exchange forces between all the proton-neutron pairs. He calculates the corresponding eigenvalue, taking for the eigenfunction of the system the product of two totally antisymmetric eigenfunctions (for the simultaneous exchange of both the space and the spin coordinates), the one relating to the protons and the other to the neutrons. He thus reaches the conclusion that if the Coulomb interaction is neglected, the energy of the system is proportional to the number of particles of which it is composed; in other words he shows quantitatively how, with only Majorana exchange forces, it is possible to obtain the saturation both of the density and the binding energy of the nuclei.

<< At about the same time of the third paper by Heisenberg, Wigner published a paper on the mass defect of deuteron and helium. In contrast to Heisenberg and Majorana, who used exchange forces, Wigner describes the neutron-proton interaction with an "ordinary" attractive short-range potential. He knew Heisenberg's papers but "he disliked exchange forces". Other theoreticians at the time rejected the idea of obtaining saturation by introducing a repulsive core, as it was suggested by the analogy with the inter-atomic forces in molecules or solids. Majorana, for example, noted explicitly: such forces would be aesthetically unattractive. In his paper Wigner first showed that there must be a

sufficiently deep potential well to have any bound state of the proton-neutron system. Therefore the existence of the deuteron gives a definite connection between the width of the proton-neutron potential and the depth of it. Then, by assuming the value of the width of the potential well obtained from the experimental results on the neutron-proton elastic scattering, Wigner showed that it becomes possible to compute the mass defect of other nuclei. Such computations were carried out by Wigner for helium and yielded values greater than the mass defect of deuterium by a large factor, in agreement with experiments. An important idea contained in Wigner's paper was that the very much greater binding energy per nucleon of the a particle with respect to the deuteron is a consequence of the short-range of the neutron-proton interaction. In the deuteron one of the particles, let us say the neutron, remains out of the potential well for a large fraction of the time so that their binding energy is reduced. This result brought Wigner to propose, a few months later, the idea of zero-range nuclear forces. Such a scheme, however, had to be abandoned when, about two years later, L.H.Thomas showed, "in a very clever paper", that for a given deuteron binding energy, the binding energy of three nucleons, ^{3}H and ^{3}He, increases indefinitely as the range is decreased, so that zero range would lead to an infinite binding energy for mass number $A = 3$.

<< Thus at the beginning of 1933 the types of nuclear forces proposed by various authors were: (1) ordinary forces or Wigner forces, as they are frequently indicated in the literature; (2) Heisenberg exchange forces; (3) Majorana exchange forces. A third type of exchange forces was proposed in 1936 which exchanges the spin of the two interacting nucleons leaving their position unaffected. The three operators P^{H} , P^{M} and P^{B} that applied to a two nucleon wave function perform the interchange proposed by Heisenberg, Majorana and Barlett, clearly have the following properties: $P^{\mathrm{H}} = P^{\mathrm{M}}\ P^{\mathrm{B}}$; with $(P^{\mathrm{H}})^2 = (P^{\mathrm{M}})^2 = (P^{\mathrm{B}})^2 = 1$.

In 1936, however, Yukawa had already proposed the existence of a particle of an intermediate mass and spin zero (the meson) as the mediator of the nuclear forces and the distinction between Wigner forces and exchange forces had become a consequence of the value (te or zero) of the electric charge of the exchanged meson. In spite of the recognized superiority of the "meson field" approach, there are many good reasons for using, even today, some "phenomenological potential", for representing the nucleon-nucleon interaction at low energy ($<< m_\pi c^2 = 140$ MeV). In some of the expressions of this type still used today, there appear addictive terms corresponding to Wigner, Heisenberg and Majorana forces.

<< Let me go back to 1933. By adjusting the potential well of the Majorana forces to be attractive for even values of the angular momentum ℓ of the relative motion of a proton and a neutron, the potential becomes repulsive for odd values of ℓ. This alternation of the sign of the forces for even and odd ℓ is a characteristic feature of exchange forces, and can be used, as pointed out by Wick, for deciding whether the forces acting between neutron and proton are exchange forces or ordinary ones. If the de Broglie wave length is comparable to the range of the forces, it becomes hard to deflect the neutron and small deflections are more likely than large ones. But exchange forces interchange the nature of the particles and the incident neutron, which tends to continue in the forward direction, becomes a proton and the outgoing neutron tends to go backward in the centre of mass frame. >>

3 A few elementary historical notes on the Neutrino

During the 1920's physicists believed matter was built of electrons and protons only (which they even called "negative and positive electrons"). They were therefore attempting at explaining the atomic nucleus as composed of protons and (negative) electrons, basing themselves also on the observations that protons could be knocked out of light elements by alpha particle bombardment, while electrons emerged in radioactive beta decay (especially from very heavy nuclei). Majorana himself had tried to work out for the nucleus a consistent theory of such a type: unsuccessfully, of course –as we know from the extremely vast amounts of scientific manuscripts[3-7] he left unpublished–. Any other elementary constituent of the atom would have been considered superfluous.

But, in 1930, Wolfgang Pauli postulated the existence of the neutrino to explain the continuous distribution of energy of the electrons emitted in beta decay, which seemed to imply a non-conservation of energy in such radioactive decays. Only with the emission of a third particle could momentum and energy be conserved; avoiding moreover apparent spin and statistics anomalies. Indeed, Pauli suggested that a neutral particle of small mass might accompany the electron in nuclear beta decay, calling it (until Chadwick's discovery) the "neutron", a name corrected later on into "neutrino". Indeed, when J.Chadwick discovered a much more massive

nuclear particle, in 1932, and also named it a neutron, this left the two particles with the same name. The name *neutrino* was playfully coined by Edoardo Amaldi, to resolve the confusion, during a conversation with Enrico Fermi at the renowned Institute of Physics in *Via Panisperna* street at Rome, as a jocular diminutive of the word neutron. It was in fact a pun on "neutrone", the Italian equivalent of neutron: the *-one* suffix being an augmentative in Italian, so that neutrone could be read as the "big neutral thing"; while *-ino* was replacing the augmentative with a diminutive suffix, the word *neutrino* meaning therefore in Italian the "small neutral thing". Such a term was adopted by Fermi in the Paris Conference of July 1932, and in the 1933 Solvay Conference, where even Pauli accepted and used it. Then, it spread in the international scientific community, especially when Fermi used it in 1933 in his fundamental theoretical paper on beta decay, famous as being the first theory of weak interactions. In fact, it was the precursor to the subsequent theory in which the interaction between protonneutron, and electronantineutrino, is mediated by a virtual W boson [incidentally, the weak interaction theory, born with Fermi in 1933, was concluded –in a sense– with the experimental revelation at Cern fifty years later, in 1983 of the heavy bosons W and Z: that is, of the "heavy photons"; a discovery attributed mainly to Carlo Rubbia, another Italian, who received his Nobel price in 1984].

Upon the prediction and discovery of a second and third neutrino, it became necessary to distinguish between the different types of neutrinos. Pauli's neutrino is now called the electron neutrino, while the second and third neutrinos is identified as the muon neutrino and the tau-neutrino, respectively.

3.1 Pauli's letter of the 4th of December 1930

It is known that Wolfgang Pauli proposed the existence of the neutrino in a (machine-typed) letter sent by him from Zurich to the physicists who were going to meet in Tuebingen on December 4th, 1930, asking a colleague to take his letter to that Meeting and remain at the disposal of the audience for any needed further information.

Il follows a translation into English of his

Open letter to the group of radioactive people at the Gauverein Meeting in Tubingen:

Physics Institute
of the ETH
Zurich

Zurich, Dec. 4, 1930
Gloriastrasse

Dear Radioactive Ladies and Gentlemen,

as the bearer of these lines, to whom I graciously ask you to listen, will explain in more detail, prompted by the "wrong" statistics of the N and Li6 nuclei and the continuous beta spectrum, I had recourse to a desperate remedy to save the "exchange theorem" of statistics and the law of conservation of energy. Namely, to the possibility that there could exist in the nuclei electrically neutral particles, that I will tentatively call "neutrons", which have spin 1/2 and obey the exclusion principle, and which further differ from light quanta in that they do not travel with the velocity of light. The mass of my "neutrons" should be of the same order of magnitude as the electron mass and in any event not larger than 0.01 proton masses. The continuous beta spectrum would then become understandable by the assumption that in beta decay a "neutron" is emitted in addition to the electron such that the sum of the energies of the neutron and the electron is constant...

I agree that my remedy could seem incredible because one should have seen these "neutrons" much earlier if they really exist. But only the one who dare can win, and the difficult situation, due to the continuous structure of the beta spectrum, is lighted by a remark of my honoured predecessor, Mr. Debye, who told me recently in Bruxelles: "Oh, it's well better not to think about this at all, like about new taxes". From now on, every solution to the issue must be discussed. Thus, dear radioactive people, look and judge.

Unfortunately, I cannot appear in Tubingen personally, since I am indispensable here in Zurich because of a ball on the night of 6/7 December.
With my best regards to you, and also to Mr. Back.
Your humble servant,
W. Pauli

Pauli thought his proposal of the "neutron" was too speculative, and did not publish it in a scientific journal until 1934, by which time Fermi had already developed a theory of beta decay (1933) incorporating the neutrino.

3.2 Fermi's costruction of the theory of β-decay and of Weak Intercations

After Pauli suggested the existence of electrically neutral neutrinos, and Fermi made them the basis –to use the words of F.Wilczek, Nobel laureate– of an impressive, quantitative theory of beta decay. This happened[28,29] in 1933, exacly 300 years after the 1633 condamnation of Galileo and his School.

If I am allowed to insert a digression, let me provide an idea of what the activities of Fermi and his group meant to Italian physics and science –and later on for the American ones, as it is more widely known–, by recalling that the Italian physical sciences had once before achieved a position of international superiority –with Galileo. But while the condemnation on July 22nd, 1633, by the Power existing at that time in Italy (the Church) did not have serious consequences for Galileo himself, it proved disastrous for the School of Galilean physics, which could have continued on as the finest in the world. The vast, promising scientific movement founded by Galileo was cut at the roots by the condemnation of the master, such that physics then totally transferred beyond the Alps. John Milton, recalling a visit to the the "famous Galileo, by now old and a prisoner of the Inquisition" (Galileo died in 1642), summed up the situation brilliantly, noting in 1644 that *the state of servitude to which science had been reduced in its homeland was the reason why the Italian spirit –so alive before– was by now extinct, and for many years thereafter everything that was written was nothing more than flattery and platitudes.* Almost two centuries passed before another great physicist surfaced: Alessandro Volta. Volta created a branch of research that lead to predominantly technological applications by Antonio Pacinotti, Galileo Ferraris and Augusto Righi and, later, to those of Guglielmo Marconi. But this did not yield a true school of physics. So by the end of 1926, when Fermi obtained the chair of theoretical physics in Rome, Italy was certainly not prevalent in the world of physics. It was only Fermi

who, three centuries after Galileo, managed to generate an extensive, modern movement within the physical sciences. For example, the article which initiated Fermis theory of "weak interactions" was released in 1933, exactly three hundred years, as we were saying, after the final sentencing of Galilean theory. This digression into the past might help to clarify the cultural significance, as well as the difficulty, of the re-conquest of Italian physics in the last century. In this context, the presence of Ettore Majorana is potentially crucial. As we know –and shall soon recall–, he was beneath no other theoretical physicist or physico-mathematician. But, as a pioneer far ahead of his time (and due also to his shyness and self-critical nature), only a few of his articles were quickly understood, appreciated and utilized. Moreover, science lost the man, his work and his leadership very early on. Certainly, if the Italian theoretical physics had been able to draw upon the genius of Majorana (and his students), together with Fermi, for a longer period, the consequences could have been enormous, perhaps unimaginable. This does not change the fact that the fruits of Ettore Majoranas farsighted intellect can be seized –and are more and more seized– still today - not only in Italy, but all over the world.

Fermi first submitted his "tentative" theory of beta decay to the famous science journal *Nature*, which rejected it "because it contained speculations too remote from reality to be of interest to the reader". Nature later regretted that rejection... Fermi then submitted revised versions of the paper to Italian and German journals, which accepted and published them in those languages[28,29] in 1933, and then in 1934. The paper, of course, did not appear at the time in English: An English translation of the seminal paper was published only in 1968 in the *American Journal of Physics.* Fermi found the initial rejection of the paper so troubling that he decided to take some time off from theoretical physics, and do only experimental physics. This had a positive side-effect, leading shortly to his famous work with activation of nuclei by slow neutrons.

As we already said, Fermi's theory of beta decay included the neutrino, presumed to be massless as well as chargeless. Treating the beta decay as a transition that depended upon the strength of the coupling between the initial and final states, Fermi developed a relationship which is now referred to as Fermi's Golden Rule. Namely, Fermi's Golden Rule says that the transition rate is proportional to the strength of the coupling between the initial and final states, factored by the density of the final

states available to the system. But the nature of the interaction which led to beta decay was still unknown in Fermi's time. It took some 20 more years to work out a detailed model of weak interactions which fitted the observations.

3.3 Just a mention of Majorana neutrino

While Fermi was constructing his beta-decay teory in 1933, the same year Majorana was working on his symmetric theory of particles and antiparticles (initiated probably one year before, already), that he had in mind to apply to neutrinos/antineutrinos.

As we have said, from the manuscripts left unpublished by Majorana, it appears that he was formulating also the essential lines of his symmetrical theory of particles and anti-particles during those years, 1932-1933. Even though Majorana published that theory years later, on the point of participating in the 1937 competition for professorship: "Teoria simmetrica dell'elettrone e del positrone"; a publication that was initially noted almost exclusively for having introduced the Majorana representation of the Dirac matrices in a real form.

Once Majorana had returned from abroad, where he met several other important personalities including Bloch, Bohr and Weisskopf, he did not publish any papers for several years. But his research activity during this period, which focused mainly on field theory and quantum electrodynamics, is well testified by a number of unpublished scientific notes, part of which have been reproduced by us in refs.[5,6] and [4,3]. In 1937, however, probably after being invited by Fermi to compete for a full professorship, Majorana published what was to become his most famous paper: "Symmetric theory of electrons and positrons," in which he introduced the so-called Majorana neutrino hypothesis. A consequence of this theory is that a neutral fermion can coincide with its anti-particle: This hypothesis was revolutionary because it argued that the antimatter partner of a given matter particle could be the particle itself. And this was in direct contradiction to what Dirac had successfully assumed in order to solve the problem of negative energy states in quantum field theory (i.e., the existence of the positron).

But Majorana was just interested –among the others– in eliminating the "Dirac sea" postulate. Let us use the words used by Fermi when

recommending Majorana to the Ministry[1] for attributing to him a full-professorship independently of the 1937 Competition:

<< In a recent paper he devised a brilliant method for treating positive and negative electrons in a symmetric way, finally eliminating the need for the highly artificial and unsatisfactory hypothesis of an infinitely large electric charge diffused throughout space, a question which had been unsuccessfully confronted by numerous other scholars >>.[1]

Anyway, with unprecedented farsightedness Majorana suggested that the neutrino, which had just been postulated, as we know, by Pauli and Fermi, could be such a particle. This would make the neutrino unique among the elementary particles and, moreover, enable it to have mass: a property that favoured the possibility of neutrino oscillations (a phenomenon, predicted by B.Pontecorvo, and later on experimentally verified).

As with Majorana's other writings, this article also started to have luck only decades later, beginning in 1957. Now expressions like Majorana spinors, Majorana mass, and Majorana neutrinos are are well-known to be highly fashionable. As we already mentioned, Majorana's publications (still little known, despite it all) can be regarded as a goldmine for physics. For example, it has been recently observed by C. Becchi how, in the first pages of that paper, a clear formulation of the quantum action principle appears: the same principle that in following years, for instance through Schwinger's and Symanzik's works, has brought about quite important developments in quantum field theory. Moreover, theoreticians[14,31], and especially mathematicians, have more recently noticed, and worked out, the quite *important* observation that Majorana spinors imply Majorana Algebras and Majorana Involutions, which admit of extraordinary applications, for instance in the study of the famous *Monster Group*: See refs.[32,33].

Let us recall at this point that a very large part of Majorana's work was left unpublished by him. We have in our hands his Master thesis on "The quantum theory of radioactive nuclei", 5 notebooks (*"Volumetti"*), 18 booklets (*"Quaderni"*), 12 folders with spare papers, and the set of the lecture notes for the course on theoretical physics held at the University of Naples. For the interest of E. Amaldi, these manuscripts were deposited by

Luciano Majorana (Ettore's brother) at the "Domus Galilaeana" of Pisa, Italy. We already stated that our analysis of those manuscripts allowed us to ascertain that all the existing material, except that for the lectures delivered at the Naples University, seems to have been written by approximately 1933; even the rough copy of his last article, which Majorana published in 1937, seems to have been ready by 1933, the year in which the discovery of the positron was confirmed. Indeed, we don't know too much of what he did in the following years, from 1934 to 1938, except for a series of 34 letters written by Majorana between March 17, 1931, and November 16, 1937, in reply to his uncle Quirino —a renowned experimental physicist and at that time the president of the Italian Physical Society— who had been pressing Majorana for theoretical explanations of his own experiments. Such letters, which reveal once more as Majorana was deeply knowledgeable even about experimental details, were copied for us in the seventies by Quirino's daughter Silvia Majorana Toniolo, and much later (1989) transmitted by us to G.Dragoni, who ended publishing them (due to their technical nature, in our book[1] we could publish only few of them). By contrast, his sister Maria recalled that, even in those years, Majorana, who had reduced his visits to Fermi's Institute, starting from the beginning of 1934 (that is, after his return from Leipzig), continued to study and work at home many hours during the day and at night. What went on he doing. From a letter of his to Quirino, dated January 16, 1936, we find a first answer, because we get to learn that Majorana had been occupied "since some time, with quantum electrodynamics"; knowing Majorana's love for understatements, this no doubt means that by 1935 Majorana had profoundly dedicated himself to original research in the field of quantum electrodynamics.

This seems to be confirmed also by a text written by Majorana in Frence, and recently retrieved[30], where the author dealt with a peculiar topic in quantum electrodynamics: *An interesting topic for us, since he actually dealt again with a hole theory which eliminated the necessity of the the unaesthetic postulate of the "Dirac sea"*. It is instructive, for this, just to quote directly from the Majorana's paper: as we shall do in our Appendix B.

Let us go back to Wilczek's words[31]. After that Fermi made neutrinos << the basis of an impressive, quantitative theory of beta decay, it became interesting to reconsider whether one could have spinning particles that are

their own antiparticles. Could one, specifically, have a version of the Dirac equation that involved real fields? This was a mathematical question asked, and answered, by Majorana >>.

The exceptional theory of neutrinos by Majorana would lead us too far, and we are glad to be able to confine ourselves to refer the reader to the excellent presentations of it in works like [14,31], and refs. therein.

Let us only stress that, even if the important experiments presently performed all over the world (e.g., in USA, Japan, Italy,...) haven't revealed yet if neutrinos are Dirac's or Majorana's, nevertheless, in condended matter physics, structures have been found several times that are "Majorana fermions": see Refs.[34-36].

4 Reply to some recent (unjustified) rumors about Fermi and Majorana

4.1 E.Fermi did NOT write down himself the last E.Majorana's article...

We have been told that rumors arose, e.g. in the USA, about the fact that E.Fermi himself could have written down the last E.Majorana's (1937) article, on neutrinos, on the basis of Majorana's idea. A fact like that is rejected by all people who have been studying Majorana's writings since decades (we, e.g. discovered E.M.'s epistulary and documents[1] in the years 1969-1972 –examining at the same time[3] his scientific papers deposited at the 'Domus Galilaeana" of Pisa– and started to investigate them all about 45 years ago) for the reasons that: (i) the characteristic E.M.'s sharp style appears the same in all his papers, while it is quite different from Fermi's style; (ii) E.M. had practically prepared his 1937 article by 1933, as results from many documents handwitten by him and to be found e.g. in refs.[6,5], and via the Links, c/o http://www.domusgalilaeana.it/index.php?, to *Quaderno* 13, as well as to *Quaderno* 17, especially around page 20, and after page 74; (iii) Enrico Fermi, even if recognized E.Majorana to be much higher than himself in theoretical physics[1], was a big man, and never would have acted as a Majorana's "secretary"...!

This rumor seems to have been generated by a sentence in ref.[14], due

probably to a wrong translation into English of a phrase contained in E.Amaldi's memoirs about Majorana. Those reminiscences appeared even as an Appendix to our book[1], because of an Amaldi's kind concession. But let us refer to the version appeared –with an English translation– as an introduction to volume [17]; and follow M.Casella's[37] examination. Actually, at page XXIV of [17], 8th paragraph, the second phrase might me misinterpreted by an unmindful translator. That compounud sentence is made of three clauses, and takes a new (erroneous) meaning if the subject of the last clause is considered to be the first subject (Fermi) instead of the second (Majorana), *as if the second clause were incidental*: So that the main clause was (wrongly) regarded as made of the first and third... But the first subject is plural (Fermi and friends): hence, it could NOT be linked in any case to the third clause, especially in Italian [namely, in the original Italian phrase, it is obvious that the initial plural subject (Fermi and the various friends) cannot be the subject of the last clause, which refers on the contrary to the second subject (Majorana)].

Let us come to the actual original sentence!: << Fermi e i vari amici si adoperarono in questo senso, e Majorana infine si convinse a gran fatica a prendere parte al concorso, e mandò alla stampa su "Il Nuovo Cimento" il lavoro sulla teoria simmetrica dell'elettrone e del positrone.>>; wherein: "Fermi e i vari amici si adoperarono in questo senso" is the first clause; "e" is a conjunction (that could be eliminated, or replaced with "so that"); "Majorana infine si convinse a gran fatica a prendere parte al concorso" is the second clause; "e" is an ordinary copulative conjunction; "mandò alla stampa su "Il Nuovo Cimento" il lavoro sulla teoria simmetrica dell'elettrone e del positrone" is the thirdclause. In conclusion, in the original Italian, the 2nd and 3rd clauses refer to one and the same subjec (Majorana), without any doubt.

The translation of the same passage into English, present in ref.[17] itself, reads: << The problem naturally was to make Ettore enter the competition, since he did not seem to want to do so, and in any event had not published any physics papers for some years. Fermi and various friends tried to persuade him, and finally Majorana was convinced that he should take part in the examination, and he sent his paper on the Symmetrical theory of electrons and positrons (No. 9) for publication in "Il Nuovo Cimento".>>. According to us, even from this English translation appears that the paper was sent for publication by Majorana!

Let us consider another translation, contained in the English version of ref.[1]...: << Fermi and various friends persevered and finally persuaded Majorana, with great difficulty, to take part in the contest, who thus published his work on the symmetry of the electron and the positron in "Nuovo Cimento".>> In this case the translation could arise a doubt about the meaning of the *who* (Fermi or Majorana?): but our previous considerations, besides the logic of the speech, clarify that *who* meant Majorana.

4.2 E.Fermi went on remaining in GOOD relations with E.Majorana

Other, less recent rumors, indulge in suggesting that the relationship between Fermi and Majorana deteriorated, when Majorana –for his own personal reasons[1]– stopped going to the Fermi research group, after having returned from Leipzig. Somebody recalled that sometimes Majorana end Fermi discussed very loudly about physics and/or mathematics: But we think such lively discussions to be rather natural between two strong personalities, who apparently dealt with each other on an equal footing.

We want to show on the contrary, by three documents (Figs.2a,2b,3), that, when Majorana disappeared, Fermi was still feeling the highest friendship and estimation for Ettore. The first two documents (Figs.2a,2b) were discovered and first published by this author (see Ref.[1] and refs. therein), while the third one (Fig.3) was got and published by E.Amaldi. Their content can be published, just quoting the source; but their anastatic reproduction is restricted by copyrights.

First document: – Letter to the Ministry of Education by the Judging Commission (E.Fermi being the first signer) for the 1937 full-professorship Competition, on the candidate E.Majorana[1].

Our English translation is:

Rome, 25 Oct. 1937
To His Excellency The Minister of National Education – ROME
Your Excellency,
The Selection Commission to the Chair of Theoretical Physics of the Royal University of Palermo, now constituted, in conducting its operation

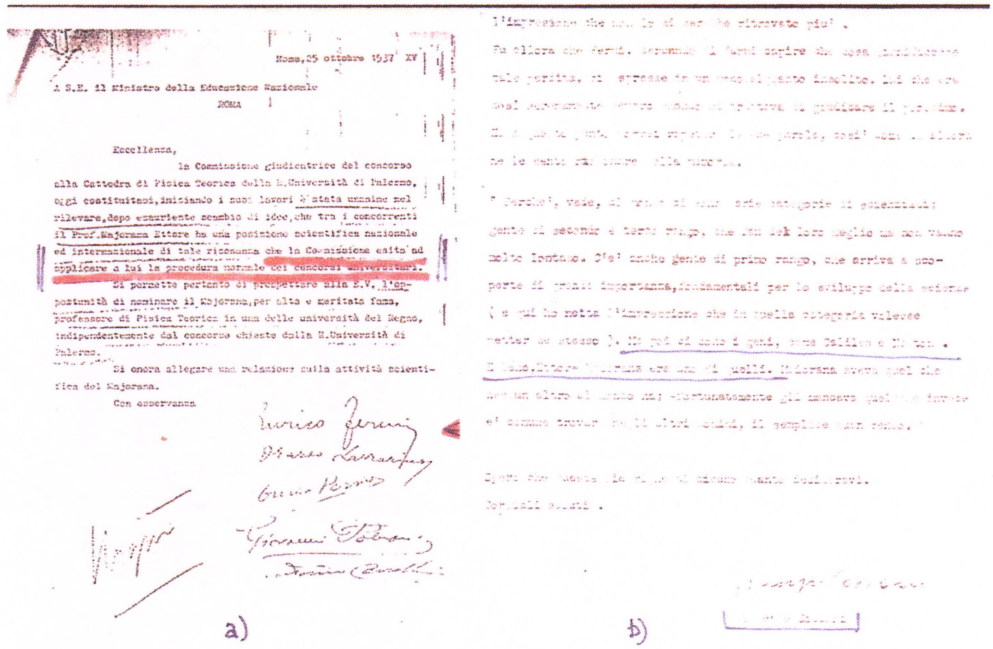


Figure 2: Fig.2(a): Letter to the Ministry of Education on the candidate E.Majorana[1], by the Judging Commission (E.Fermi being the first signer) for the 1937 full-professorship Competition; Rome, Oct. 25th, 1937: see below for its translation into English. Fig.2(b): We reproduce here the principal (final) part of C.Cocconi's testimonial, written at E.Amaldi's request, that recalls how Fermi compared E.Majorana to *geniuses like Galileo and Newton.* – Anastatic reproduction restricted by the relevant copyrights.

was unanimous in identifying, after a thorough exchange of opinions, that among the nominees, Prof. Ettore Majorana has a national and international scientific position of such resonance that the Commission hesitates to apply to him the normal procedure for university competitions.

We therefore propose to Your Excellency the opportunity of appointing Majorana, for high and deserved reputation, Professor of Theoretical Physics in a University of the Kingdom, independently of the Competition requested by the Royal University of Palermo.

We are honored to attach a report on the scientific activity of Majorana.
Respectfully yours,
Enrico Fermi; Orazio Lazzarino; Enrico Persico; Giovanni Polvani; Antonio Carrelli

Second document: – Letter of 27 July 1938 by E.Fermi to the Prime Minister Mussolini[1] asking for an increase in the investigations to trace the disappeared E.Majorana (disappeared on March 26, 1938).[1]

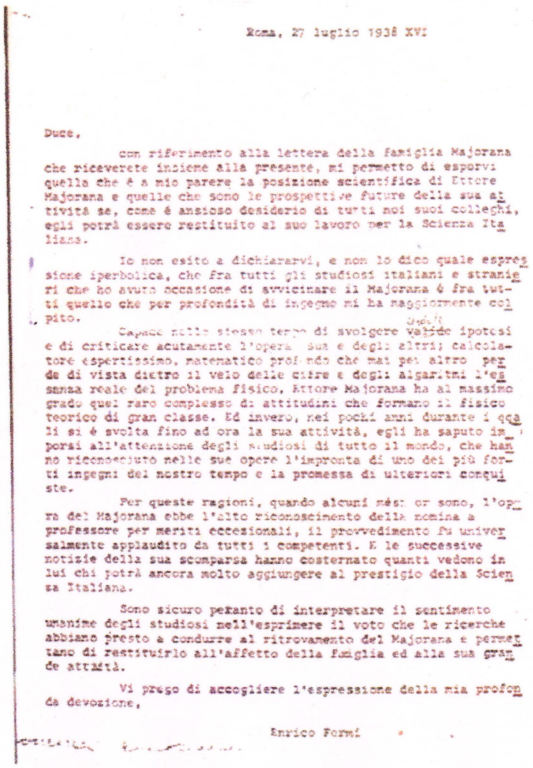
Enrico Fermi, a 1938 Nobel Prize laureate and one of the greatest physicists of our time (for his accomplishments in 1942 in Chicago perhaps his name will become as legendary as that of Prometheus...), expressed himself in an unusual way on another occasion, when wrote from Rome on July 27th, 1938, to Prime Minister Mussolini asking to intensify the search for Ettore: *"I do not hesitate to declare, and this is not hyperbole, that of all the Italian and foreign scholars whom I had the opportunity to meet, Majorana is the one who for the depth of his genius has impressed me the most.* And Bruno Pontecorvo, a direct observer, added: "A short time after his entry in Fermis group, Majorana had already acquired so much knowledge and had reached such a level of understanding of physics, that he was able to speak with Fermi about scientific problems as an equal. Fermi himself considered Ettore the greatest theoretical physicist of our time. Often he was left astounded [...]. I remember Fermis exact words: 'If a problem has already been posed, no one in the world can solve it better than Majorana'." Enrico Fermi was perhaps one of the last examples, and an extraordinary one, of a great theorist who was also a great experimenter. Majorana, instead, was a pure theorist. Indeed (to use the same words as Fermi in the continuation of his letter to Mussolini) Ettore possessed, to the highest degree, that rare combination of skills that make up a theoretical physicist of "gran classe". Ettore 'carried' science, as Sciascia said; indeed he 'carried' theoretical physics. He was not less than a Wigner or Weyl: who, for their aptitude in physics and mathematics, were among the very few scholars for whom Ettore himself harbored unreserved admiration.

So, on the one hand, he had no propensity for experimental activities (even if forced, to be clear, he could never have made a tangible contribution to projects like the technological construction of the atomic bomb). But on the other hand, he could descend with unsurpassed and hardly-

imaginable depths into the substance of physical phenomena, seeing in them elegant symmetries and powerful new mathematical structures, or uncovering sophisticated physical laws. His sharpness enabled him to see beyond the vision of his colleagues: that is, to be a pioneer. Even his notes, written starting in 1927 when he began his transition from engineering studies to the study of physics, are not only a model of order (they are divided into topics and even have indexes), but also of originality, conciseness, and choice of the essential things only. For this reason these notes, known as the Volumetti, were suitable for publication just as they were: And indeed they have been published in 2003 by Kluwer Academic Press (in English)[5], and in 2006 by Zanichelli (in Italian)[5]. These "study" notes are in reality rich with original inventions. Even more so are the remaining manuscripts, which consist of scientific research notes only. But the publication of all these manuscripts is a heavy undertaking; and in 2009 we published with Springer (in English), by another 500 page volume[6], a *selection* of the so-called "Quaderni": which in their turn contain many, but not all, of the scientific manuscripts left unpublished[7,6] by Majorana.

Third document: – Letter of July 18, 1965, by G.Cocconi from Geneva: In Fig.2(b) we reproduce the principal (final) part of Cocconi's testimonial, written at E.Amaldi's request, that recalls how Fermi compared E.Majorana to *geniuses like Galileo and Newton.*

Majoranas fame is firmly justified through testimonials like the one below, which we owe to the mindful pen of Giuseppe Cocconi. Let us read it in full. From CERN in Geneva, Cocconi(a former collaborator of Enrico Fermi and colleague of Ettore) wrote to Edoardo Amaldi:
<< Geneva, 1965, July 18th - Dear Amaldi, in a discussion that took place long ago on the book [*later published by Accademia dei Lincei*] that you are writing about Ettore Majorana, I told you that I, too, had a tenuous contact with Majorana just prior to his disappearance. You expressed then that you wished me to describe my recollections in greater detail, so here I will try to satisfy you. After having just graduated in January 1938, I was offered, mainly by you, the opportunity to come to Rome for six months as an assistant at the universitys Institute of Physics. Once there, I was fortunate enough to join Fermi, G.Bernardini (who had taken a teaching post in Camerino a few months prior) and Ageno (himself also



Roma, 27 luglio 1938 XVI

Duce,

con riferimento alla lettera della famiglia Majorana che riceverete insieme alla presente, mi permetto di esporvi quella che è a mio parere la posizione scientifica di Ettore Majorana e quelle che sono le prospettive future della sua attività se, come è ansioso desiderio di tutti noi suoi colleghi, egli potrà essere restituito al suo lavoro per la Scienza Italiana.

Io non esito a dichiararvi, e non lo dico quale espressione iperbolica, che fra tutti gli studiosi italiani e stranieri che ho avuto occasione di avvicinare il Majorana è fra tutti quello che per profondità di ingegno mi ha maggiormente colpito.

Capace nello stesso tempo di svolgere valide ipotesi e di criticare acutamente l'opera sua e degli altri; calcolatore espertissimo, matematico profondo che mai per altro perde di vista dietro il velo delle cifre e degli algoritmi l'essenza reale del problema fisico, Ettore Majorana ha al massimo grado quel raro complesso di attitudini che formano il fisico teorico di gran classe. Ed invero, nei pochi anni durante i quali si è svolta fino ad ora la sua attività, egli ha saputo imporsi all'attenzione degli studiosi di tutto il mondo, che hanno riconosciuto nelle sue opere l'impronta di uno dei più forti ingegni del nostro tempo e la promessa di ulteriori conquiste.

Per queste ragioni, quando alcuni mesi or sono, l'opera del Majorana ebbe l'alto riconoscimento della nomina a professore per meriti eccezionali, il provvedimento fu universalmente applaudito da tutti i competenti. E le successive notizie della sua scomparsa hanno costernato quanti vedono in lui chi potrà ancora molto aggiungere al prestigio della Scienza Italiana.

Sono sicuro pertanto di interpretare il sentimento unanime degli studiosi nell'esprimere il voto che le ricerche abbiano presto a condurre al ritrovamento del Majorana e permettano di restituirlo all'affetto della famiglia ed alla sua grande attività.

Vi prego di accogliere l'espressione della mia profonda devozione,

Enrico Fermi

Figure 3: Fig.3: Letter of July 18, 1965, by G.Cocconi from Geneva: We reproduce here the principal (final) part of Cocconi's testimonial, written at E.Amaldi's request, that recalls how Fermi compared E.Majorana to *geniuses like Galileo and Newton.* Obs.: at that time photocopiers did not exist, and this is a carbon copy (existing together with a draft.

a young graduate), to engage in research regarding the products of the disintegration of "mu mesons (then called mesotrons or yukons) produced by cosmic rays. The existence of "mu mesons" had been proposed about a year earlier, and the problem of their decay was quite contemporary.
<<It was indeed while I was with Fermi in the small workshop on the second floor, he working intently at the lathe on a section of a Wilson chamber that was intended to reveal the mesons in the end range, and I busy building a mechanism to illuminate the chamber using the flash

produced by the explosion of a strip of aluminum on a shorted battery, that Ettore Majorana came in looking for Fermi. I was introduced to him and we exchanged a few words. A dark face, and that was all. It would have been a quite forgettable episode if, a few weeks later, while with Fermi in the same workshop, I had not heard the news of Majoranas disappearance from Naples. I remember that Fermi busied himself by phoning various places until, after a few days, one got the impression that no one would ever find him.
<< It was then that Fermi, trying to impress upon me the significance of this loss, expressed himself in a rather unusual way for him who was so severe when judging others. And at this point, I would like to repeat his words just as they echo in my memory: *"Because, you see, in the world there are various categories of scientists. People of second and third rank, who do their best but do not go very far. There are also people of the first rank, who make discoveries of great importance that are fundamental for the development of science (and I have the distinct impression that he would have put himself in this category). But then there are the geniuses like Galileo and Newton. Well, Ettore was one of these. Majorana had what no one else in the world has. But unfortunately, he lacked what is instead common in other men, plain good sense."* I hope these lines provide you with what you wished to know. Kindest regards,
Giuseppe Cocconi.>>

"Plain good sense": we prefer to say common sense; which may be not always good, or the best.

5 APPENDIX A

Let us put here our translation into English of the first detailed account, about the role of E.Majorana in connection with the neutron, written by E.Amaldi in ref.[23], and by us reported above in its original language (Italian) for historical reasons:

<< Majorana's interest in nuclear physics, which he had already manifested in his thesis, was strongly revived with the appearance of classic works that would lead to the discovery of the neutron at the beginning

of 1932. In reality, his renewed interest was part of a new general direction taken by Institute in Via Panisperna, where for a few years there had already been talk of abandoning, albeit gradually, atomic physics, a field in which everyone had worked on for several years, and to focus research efforts principally on the problems of nuclear physics. Towards the end of January 1932, Comptes Rendus files began arriving with the famous notes of F. Joliot and I. Curie on penetrating radiation discovered by Bothe and Becker. The first of these described how penetrating radiation, emitted from beryllium under the action of alpha particles emitted by polonium, could transfer about five million electron volts of kinetic energy to protons in fine layers of various hydrogenated materials (such as water or cellophane). To interpret these observations, Joliot-Curie had initially suggested that it was a phenomenon analogous to the Compton effect... Soon after, however, they suggested that the observed effect was due to a new type of interaction between gamma rays and protons, different to that which occurs in the Compton effect. When Ettore read these notes, he said, shaking his head: They did not understand anything, it is probably due to recoiling protons produced by a heavy neutral particle. A few days later, the issue of Nature arrived in Rome containing the Letter to the Editor submitted by J. Chadwick on February 17, 1932, which proved the existence of the neutron on the basis of a classic series of experiments ... Soon after Chadwick's discovery, several authors realized that neutrons had to be one of the constituents of nuclei and began to offer various models consisting of alpha particles, electrons and neutrons. The first to publish that the core only consisted of protons and neutrons was probably D.D. Ivanenko ... But it is certain that, before Easter of that year, Ettore Majorana had tried to produce a theory for light nuclei assuming that protons and neutrons (or "neutral proton" as they were called then) were the only constituents and that the former interacted with the latter only through exchange forces based on spatial coordinates (and not spin), if you wanted the system saturated with respect to the binding energy to be the alpha particle and not the deuteron. He mentioned this draft theory to friends at the Institute and to Fermi, who was immediately interested and advised him to publish his results as soon as possible, even if partial. But Ettore was not interested because he judged his work to be incomplete. So Fermi, who had been invited to attend the Conference of Physics that was to take place in July of that year in Paris, in the broader context of

the Fifth International Conference on Electricity, and who had chosen the properties of the atomic nucleus as his topic discussion, asked Majorana permission to mention his ideas on nuclear forces. Majorana's reply was to forbid Fermi to discuss them or, or if he absolutely had to, on the condition that he said they were the ideas of a well-known professor of electrical engineering, who was actually going to be present at the Paris Conference, and who Majorana regarded as a living example of how scientific research should not be conducted. So it was on July 7 in Paris that Fermi gave on his report on "The current status of the physics of the atomic nucleus" without mentioning the kind of forces that were later called "Majorana forces" and that essentially had already been conceived, albeit roughly, several months earlier. In the Zeitschrift fuer Physik file dated July 19, 1932, appeared Heisenberg's first work on "Heisenberg exchange" forces, i.e., forces that involve the exchange of both spatial and spin coordinates. This work had a large impact on the scientific community: it was the first attempt at a theory of the nucleus that, however incomplete and imperfect, overcame some of the difficulties associated with the principle, which until then had seemed insurmountable. At the Physics Institute of the University of Rome, everyone was extremely interested and full of admiration for Heisenberg's results, but at the same time disappointed that Majorana had not only not published anything, but also did not want Fermi to speak of his ideas in an international congress. Fermi strove again to convince Majorana to publish something, but every effort of Fermi and his friends and colleagues was in vain. Ettore sustained that Heisenberg had already said everything that could be said on the matter and that, indeed, he had probably said too much. Eventually, however, Fermi was able to convince him to go abroad, first to Leipzig and then to Copenhagen, and he had the National Research Council assign him a grant for the journey, which began at the end of January 1933 and lasted for six or seven months. His aversion to publish or otherwise reveal his findings seemed, from this episode, to be part of his general attitude. >>

6 APPENDIX B

As we said in the text, in a letter of his to Quirino, dated January 16, 1936, we learned that Majorana had been occupied "since some time, with quantum electrodynamics;" knowing Majorana's love for understatements,

this no doubt means that by 1935 Majorana had profoundly dedicated himself to original research in the field of quantum electrodynamics.

This seems to be confirmed by a recently retrieved text written by Majorana in French[30], where the author dealt with a peculiar topic in quantum electrodynamics: *Interesting for us since he dealt with a hole theory which did not imply the unaesthetic postulate of a Dirac sea.* It is instructive just to quote directly from the Majorana's paper, following the translation presented by S.Esposito in ref.[30]:

<< Let us consider a system of p electrons and put the following assumptions: 1) the interaction between the particles is sufficiently small allowing to speak about individual quantum states, so that we may consider that the quantum numbers defining the configuration of the system are good quantum numbers; 2) any electron has a number $n > p$ of inner energetic levels, while any other level has a much greater energy. We deduce that the states of the system as a whole may be divided into two classes. The first one is composed of those configurations for which all the electrons belong to one of the inner states. Instead the second one is formed by those configurations in which at least one electron belongs to a higher level not included in the n levels already mentioned. We will also assume that it is possible, with a sufficiently degree of approximation, to neglect the interaction between the states of the two classes. In other words we will neglect the matrix elements of the energy corresponding to the coupling of different classes, so that we may consider the motion of the p particles in the n inner states, as if only these states exist. Then, our aim is to translate this problem into that of the motion of $n - p$ particles in the same states, such new particles representing the holes, according to the Pauli principle.

<< Majorana, thus, by following a track due by Heisenberg, applied the formalism of field quantization to the Dirac's hole theory, obtaining the general expression for the QED hamiltonian in terms of anticommuting holes quantities. We also point out the peculiar justification of the use of anticommutators for fermionic variables given by Majorana; such use, in fact, "cannot be justified on general grounds, but only by the particular form of the hamiltonian. In fact, we may verify that the equations of motion are satisfied to the best by these last exchange relations rather than by the Heisenberg ones.

<< In the second (and third) part of the same manuscript, Majorana also considered a reformulation of QED in terms of a photon wave function, a topic which was particularly studied even in his *Quaderni* (and reported here). Majorana, indeed, reformulated quantum electrodynamics by introducing a real-valued wave function for the photon, corresponding only to directly observable degrees of freedom.

<< In some other notes, perhaps prepared for a seminar at the University of Naples in 1938, Majorana gave a physical interpretation of quantum mechanics which anticipated of several years the Feynman approach in terms of path integral, independently of the underlying mathematical formulation. The starting point in Majorana's paper was to search for a meaningful and clear formulation of the concept of quantum state. Then, the crucial point in the Feynman formulation of quantum mechanics, namely that of considering not only the paths corresponding to classical trajectories, but all the possible paths joining an initial point with the end one, was introduced after a discussion on an interesting example of the harmonic oscillator. We also stress the key role played by the symmetry properties of the physical system in the Majorana analysis; a feature which is quite common in papers of this author. >>

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REGARDING THE STRUCTURE OF QUARKS AND HADRONS

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Abstract

Using quantum oscillators in the semi-quantum IQO model, we define electric charge, isospin, and strangeness of quarks. In addition, based on the geometric structure of (u, d, s) quarks, we develop the structures of light mesons (pions) and strange mesons (K), explaining the difference between neutral kaons K_{long} and K_{short}. We also develop the geometric forms of (c, b, t) quarks, and demonstrate why there are only six fundamental quarks. Finally we give the structures of the nucleons (p,n) and of the Xi particle.

Keywords: massive coupling; "Aureus" ratio; hypothesis of structure; strangeness; IQO; semi-quantum; sub-oscillator; entangled quantum vacuum; pion, kaon

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Introduction

If we associate wave behaviour with particles (see the diffraction with electrons and photons), it can be conjectured that "something" oscillates "inside" a particle. In this case, that "something" is an internal clock with a proper frequency ω_o. On this basis, we can say that there is a time is inside the particles. In the same way that we discuss the Compton wavelength $\lambda\!\!\!^{-}_c$ or the spin of a particle, we can also talk about something spatial that is "inside" it. Thus, in the same way that particles are in space-time (ST), it can be said that there is "*ST is inside the particles*".

When we discuss ST inside a particle, that is the same as discussing the "*internal structure*" of the particle. However, if one assumes that elementary particles are simply *points* in ST, then one cannot consider the internal composition of other sub-particles, such as nuclei or nucleons. To consider both internal oscillations and particle structures, the concept of an internal structure in terms of "coupled oscillators" must be permitted. If we recall that in quantum mechanics (QM), fields are represented as a set of coupled quantum oscillators, then giving particles an internal structure of oscillators essentially refers to a "*hypothesis of structure*" [1]. We previously discussed the geometric structure of elementary particles based on the standard model when we showed that (u, d, s) quarks are physical systems having a well-defined spatial geometric structure of coupled oscillators. In this paper, we describe the geometric structure of coupled oscillators that represents (c, b, t) quarks, as well as some massive hadrons, such as protons, pions, and kaons.

1. Hypothesis of structure

1.1 Additional coupling

Recall that any massive object can be seen as in "*movement in time*" [1] with imaginary velocity given by the constant c.

This uniform motion in time recalls once again the "clock" that exists inside every particle-object as a periodic "motion", with proper frequency ω_o, which corresponds to $\omega_o \Leftrightarrow \tau$, where ($\tau$) is the proper time.

The proper characteristic of a massive particle that is associated with the proper time (τ) of an object coincides with the proper **mass** (m_0) of that object. When discussing the mass or mass energy of a particle, it is the same as discussing the time of the clock that is inside them: $\omega_o \Leftrightarrow \tau \Leftrightarrow m_o$.

Then, based on QM [1]:

$$\left\{\begin{matrix} E_0 = mc^2 \\ E_0 = \hbar\omega_0 \end{matrix}\right\} \Rightarrow \left\{ m = \frac{\hbar\omega_0}{c^2} \right\} \tag{1}$$

If the frequency ω_0 generates the proper time τ of a massive particle [$\tau=\hbar/mc^2$], then for symmetry, there exists a wavelength $\lambda\!\!\!^{-}_0$ that generates the "*proper space*" of the particle. Following De Broglie, we have:

$$\left\{\begin{matrix} p_0 = mc \\ p_0 = \hbar\dfrac{2\pi}{\lambda_0} \end{matrix}\right. \quad \Longrightarrow \lambda\!\!\!^{-}_0 = \frac{\hbar}{mc} \equiv \lambda\!\!\!^{-}_c \tag{2}$$

We assert that $\lambda\!\!\!^{-}_c = \hbar/mc$ (i.e., the Compton wavelength) defines the spatial step of the proper ST of the massive particle. Now, combining the equation of the relativistic energy with the equations of De Broglie and Einstein, we have:

$$\left\{E^2 = m^2c^4 + p^2c^2 \quad \Leftrightarrow \quad \omega^2 = \omega_0^2 + k^2c^2\right\} \tag{3}$$

The second equation is the dispersion relation of waves, as described by the Klein-Gordon equation:

$$\left\{\frac{\partial^2\Psi(x,t)}{\partial t^2} = c^2\frac{\partial^2\Psi(x,t)}{\partial x^2} - \omega_0^2\Psi(x,t)\right\} \tag{4}$$

This equation also describes the oscillations in a set of pendulums coupled through springs [1][2].
As is well known, Klein-Gordon's wave equation also describes the scalar field associated with a massive particle with zero spin:

$$\left\{\frac{\partial^2\Psi(x,t)}{\partial x^2} - \frac{\partial^2\Psi(x,t)}{c^2\partial t^2} = \left(\frac{mc}{\hbar}\right)^2\Psi(x,t)\right\} \Leftrightarrow \left\{\nabla^2\Psi(x,t) = \left(\frac{mc}{\hbar}\right)^2\Psi(x,t)\right\} \tag{5}$$

However, there are also scalar fields Ξ(x, y, z, and t) with zero spin that are not associated with massive particles.

We conjectured [1] that mass is a physical expression of the proper frequency ω_0 related to a particular elastic coupling, which is in addition to the one already existing between the oscillators of the massless scalar field (Ξ). This "*additional coupling*", which produces the mass in a scalar field (Ξ), has been referred to as a "*massive coupling*". Then, we conjectured that the massive particle-field (Ξ) is created by a "transversal coupling" ($\mathbf{T_0}$) between the chains of oscillators of the scalar base field (Ξ). This can be represented figuratively as shown in Fig. 1.

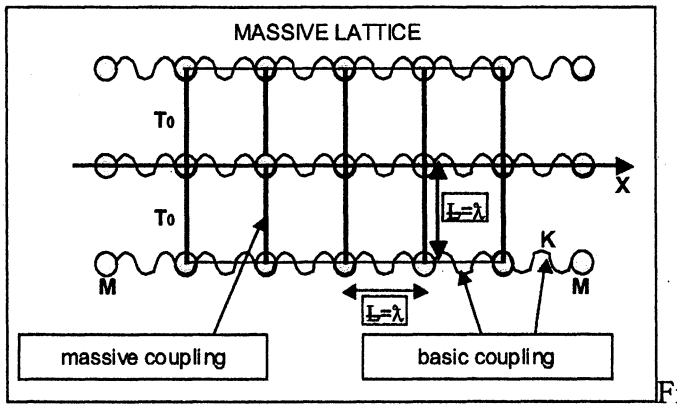

Fig. 1

Massive particles are constructed by the transversal additional coupling on an Ξ-scalar field, and this additional coupling translates the internal structure of a particle of "coupled oscillators" into geometric form. In fact, in the "Hypothesis of Structure" [1], we described a proton as having a pentagonal geometric structure in which the constituent three quarks are coincident with three triangles:

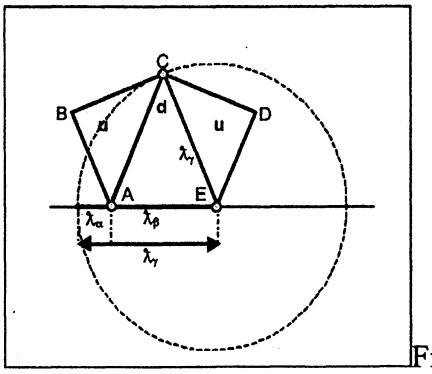

Fig. 2

Thus, **a proton is an "Aurea" particle:** *Then we can consider the three triangles [(u), (u), and (d)] as three "coupled" quarks that constitute the proton.* In the *structure hypothesis*, if a quark is an elementary particle, then it is possible that: **a quark can be represented by three elastically coupled quantum oscillators.** This hypothesis allows us to represent [1] the (u, d, s) quarks as structures of coupled quantum oscillators. To say this another way, it is similar to three "spheres" being placed at the vertices of an Aureus triangle and connected by "springs" (*"junction oscillators"*). Because the three quantum oscillators constitute a unique physical object, i.e., a unique quark, they cannot be detected separately, as shown in Fig. 3:

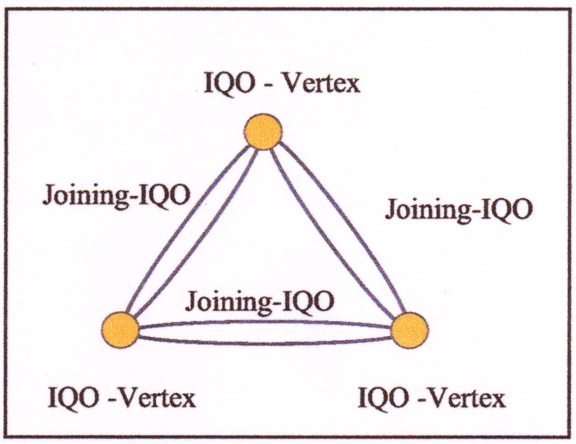

Fig. 3

On this basis, we discussed a "*sub-structure*", which is applicable only to "particular" quantum oscillators that are coupled to other oscillators.

1.2 An IQO

We recall now (you see [1]) quantum oscillators with sub-units of oscillation, or "**sub-oscillators**". A quantum oscillator with a sub-structure is referred to as "**IQO**" [3] [1]. The presence of two components in an oscillator causes us to believe that the energy of the "quanta" should be distributed between the two oscillating components:

$$\left[H_{(n)}\right]=\left[U_{(n)}+K_{(n)}\right]=\left[\left(U_{(n)}\right)_{el}+\left(K_{(n)}\right)\right]=\left[(2n+1)\left(\frac{1}{4}\hbar\omega\right)_{el}+(2n+1)\left(\frac{1}{4}\hbar\omega\right)_{in}\right] \qquad (6)$$

This causes a double structure of the operators (a, a^+) with components elastic and inertial. In a structure with two components, elastic and inertial, and two sub-oscillators, the **"quantum"** is composed of two (ε = ½ hν) semi-quanta. The energy values can are **(ε = ¼ hν),** which is referred to as an **"empty semi-quantum"** and has the symbol (**o**), or [ε = (½ hν)], which is referred to as **"full semi-quantum"** and has the symbol (•). Therefore, an IQO [ε_n= (n+½) hν)] will be represented by an empty semi-quantum (ε(**o**) = ¼ hν), and full semi-quantum [ε (•) = (½ hν)]. Thus, [ε_n = (n+½) hν) = (n(½+½) +(¼+¼)) hν]. In this oscillation theory, the annihilation operator (a) and the creation operator (a^+) can be represented by new operators built on the full semi-quantum (•) and empty semi-quantum (**o**):

$$\left\{\begin{array}{l}\hat{a}_r(t) = (\hat{o})_{el}\left[\exp(-ir'\omega t)\right] + (\hat{\bullet})_{in}\left[\exp(-i(r'\omega t - \pi/2))\right] \\ \hat{a}_r^+(t) = (\hat{\bullet}^+)_{el}\left[\exp(ir'\omega t)\right] + (\hat{o}^+)_{in}\left[\exp(i(r'\omega t - \pi/2))\right]\end{array}\right\} \tag{7}$$

If we omit the phase but highlight the direction of rotation (i.e., **cl**ockwise (**cl**) or –anticlockwise (**cl**)), in eq. (7) we have the following representative matrix:

$$\boxed{\begin{pmatrix} (o_{el})_{(cl)} & (\bullet_{in})_{(cl)} \\ (\bullet^+_{el})_{(\underline{cl})} & (o^+_{in})_{(\underline{cl})} \end{pmatrix} \equiv \begin{pmatrix} (o_{el}) & (\bullet_{in}) \\ (\bullet^+_{el}) & (o^+_{in}) \end{pmatrix}} \tag{8}$$

An oscillator with two sub-oscillators can have a bi-dimensional representation, as shown in Fig. 4.

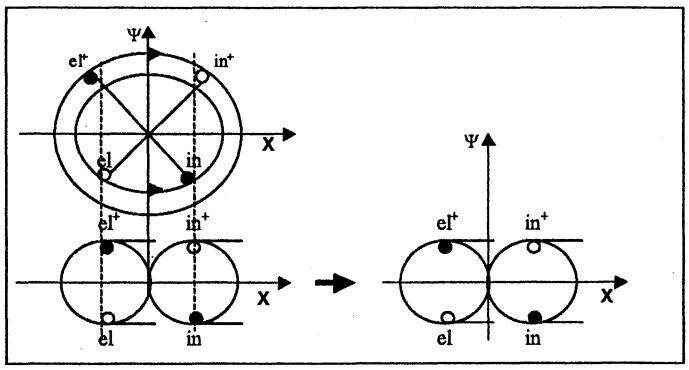

Fig. 4

Two IQO (Ψ_1, Ψ_2) can be combined:

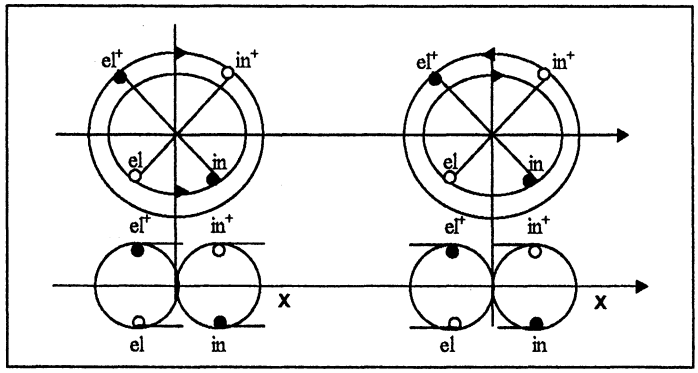

Fig. 5

We can combine (Ψ_1, Ψ_2) using the $\oplus$ operation [3]:

$$(\Psi_1 \oplus \Psi_2) = \left\{\hat{\Psi}_1 \left| \hat{\Omega} \right| \hat{\Psi}_2\right\} \tag{9}$$

where the right side of Eq. (9) contains the IQO representative matrices and Ω-operation, which is defined as:

$$\hat{\Omega} = \left(\overline{\chi} \cdot \hat{\Sigma}_{(\bullet \Leftrightarrow \circ)} \cdot \hat{\varphi}\right) = \cdot \left[\left(\overline{\chi}\right)\left(\overline{\Sigma}(\bullet \Leftrightarrow \mathrm{o})\right)\begin{pmatrix} e^{-i\Delta\varphi} & 0 \\ 0 & e^{i\Delta\varphi} \end{pmatrix}\right] \tag{10}$$

Where

- (φ) denotes the reduction of the wave function (Ψ) between phase shifts

$$\hat{\varphi}(0) = \begin{pmatrix} e^{-i\Delta\varphi} & 0 \\ 0 & e^{i\Delta\varphi} \end{pmatrix}_{\Delta\varphi=0} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \tag{11}$$

- (Σ) is the operation representing the energy exchange between semi-quanta of different two IQO, (exchange of full semi-quanta ($\bullet$) of the first IQO with empty semi-quanta (o) of the other: [($\bullet$) $\Leftrightarrow$(o)])
- (X) is the operation representing the diagonal coupling of matrix elements

then:

$$\left\{\left[\begin{pmatrix} o_{el} & \bullet_{in} \\ \bullet^{+}_{el} & o^{+}_{in} \end{pmatrix} \oplus \begin{pmatrix} o_{el} & \bullet_{in} \\ \bullet^{+}_{el} & o^{+}_{in} \end{pmatrix}\right] = \left[\begin{pmatrix} \bullet_{el} & o_{in} \\ o^{+}_{el} & \bullet^{+}_{in} \end{pmatrix} + \begin{pmatrix} \bullet_{el} & o_{in} \\ o^{+}_{el} & \bullet^{+}_{in} \end{pmatrix}\right]\right\} \qquad (12)$$

and we obtain $[(\Psi_1 \oplus \Psi_2) \rightarrow (\Phi_1 + \Phi_2)]$, as showed in Fig. 6:

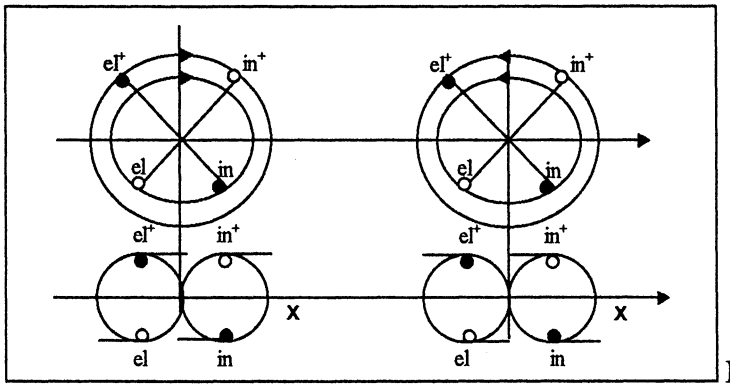

Fig. 6

It can be seen that each of the two Φ-IQO particles have only one direction of phase rotation $[(\Phi_{anti\text{-}cl}), (\Phi_{cl})]$. At the same time, note that the two particles - IQO have the opposite direction of phase rotation. Thus, an advantage in treating the field oscillators in terms of IQO is that the "**bi-dimensional**" representation (see Fig. 10) allows one to distinguish the direction of rotation of the phase associated with the oscillations. This because [3] we have determined a new degree of freedom in a quantum oscillator with semi-quanta. This degree of freedom (i.e., the direction of rotation of the phase) can be interpreted as the "**sign of the electric charge**" of a particle, where $[(\Phi_{anti\text{-}cl}), (\Phi_{cl})]$ represent particles with opposite signs of electric charge [1][3][4].

1.3 Coupling of IQO chains

The hypothesis of structure leads us to argue that any structure of coupled oscillators (IQO) can be a particle. A structure of coupled oscillators IQO involves two or more distinct chains of IQO, as shown in Fig. 7:

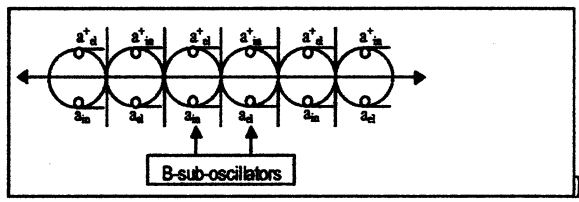

Fig. 7

It is evident that a coupling between distinct chains of IQO can be constructed with the help of "transversal" chains that "intersect" with them and thereby form an additional coupling. An elementary "geometric structure" may involve "**three**" chains of IQO and involve "isosceles triangles" (see Fig. 8):

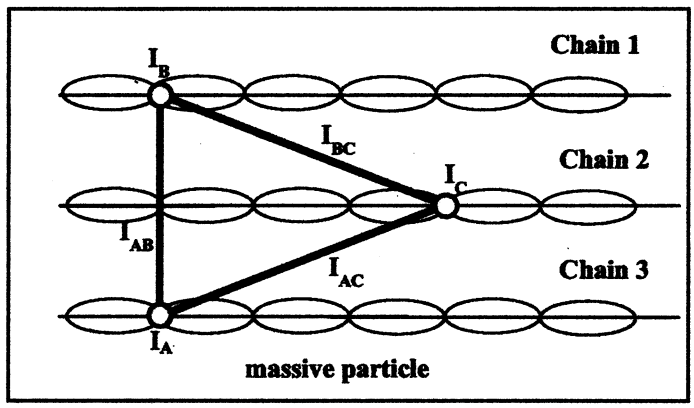

Fig. 8

Elementary couplings between distinct non-overlapping IQO chains [(1), (2), (3)] can be realized by placing transverse quantum oscillators [(I_{AB}), (I_{AC}), (I_{BC})], which join three IQO-Vertices (IQO-V) [(I_A), (I_B), (I_C)], in each of the three associated chains. The representative IQO-V matrices (i.e., with n = 2 there are 3 sub-oscillators in the IQO) will be:

$$\left\{ \begin{pmatrix} (\bullet_{el})_V & (o_{in})_V \\ (o^+_{el})_V & (\bullet^+_{in})_V \\ (o^+_{el})_V & (o^+_{in})_V \end{pmatrix}_{cl} ; \begin{pmatrix} (\underline{\bullet}_{el})_V & (\underline{o}_{in})_V \\ (\underline{o}^+_{el})_V & (\underline{\bullet}^+_{in})_V \\ (\underline{o}^+_{el})_V & (\underline{o}^+_{in})_V \end{pmatrix}_{\underline{cl}} \right\} \qquad (13)$$

where the second matrix describes the central sub-oscillator of a quantum oscillator in one of several possible configurations.

If an elementary particle is associated with a triangular structure of IQO, then we should associate a quantum of energy with it; however, if its quantum oscillators are of type $IQO_{(n=2)}$ and are six in number (i.e., three IQO-V + three IQO-J) then two pairs {[(•),(•)]+[(•),(•)]} should be associated with the structure. However, if we distribute two pairs of semi-quanta to six IQO in a "non-separated" state, then paradoxically, we obtain "**almost empty**" quantum oscillators. When we consider that each IQO in a structure is composed of coupled sub-oscillators, we can say that all sub-oscillators in the structure are in a type of vacuum state, or are "**quantum entangled**". In this way, we say that the state of elementary particles is that of an **"entangled quantum vacuum"**. In addition, we consider if a particle in an "entangled quantum vacuum " can be exposed (recall the concept of "quark confinement"). If this is the case, then it may be that these types of particles are the same as those called **"quarks"**.

2. "Aureus" Quarks

2.1 (u, d) quarks

We formulated the following hypothesis (see [1]): **an "Aurea" triangular structure of IQO with vertex angles of 72° corresponds to quark (d).** Figure 9 can then be derived from Fig. 8:

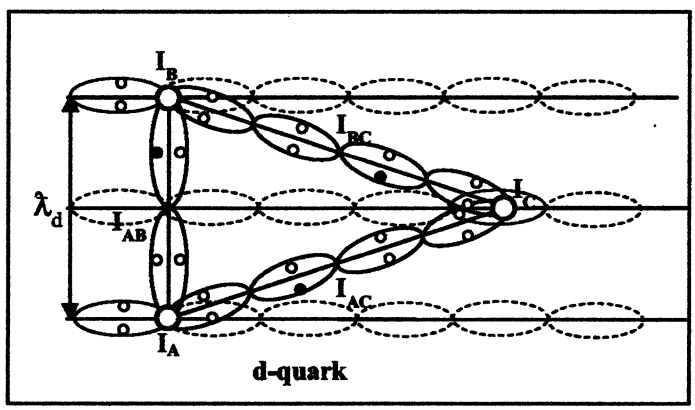

Fig. 9

With regard to the representation of sub-oscillators, the u-representation is as follows:

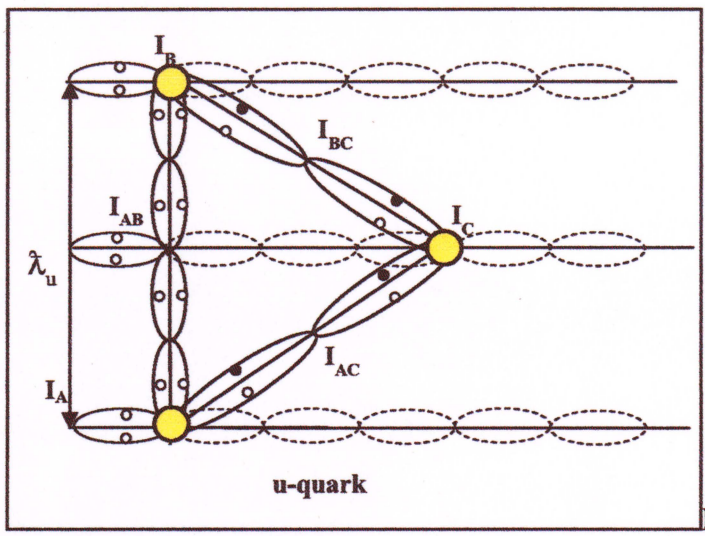

Fig. 10

According to Fig. 2, the relationship [1] between the quark masses (u, d) is given by (see the eq. 2):

$$\boxed{\begin{Bmatrix}(\hat{\lambda}_u/\hat{\lambda}_d)=\phi\\(m_d/m_u)=\phi\end{Bmatrix}} \tag{14}$$

where (ϕ) is the "Aureus" ratio (i.e., golden ratio). It has already been noted that a quark is an overlap of an IQO-V and transversal-IQO: $[(I_A \oplus I_{AB} \oplus I_B \oplus I_{BC} \oplus I_C \oplus I_{CA})]$. This last matrix represents a quark with three IQO-V (A,B,C):

$$\begin{pmatrix}(\bullet_{el})_{ABC} & (o_{in})_{ABC}\\ (...o...) & (...o...)\\ (o^{+}_{el})_{ABC} & (\bullet^{+}_{in})_{ABC}\end{pmatrix}_{cl} \Rightarrow \begin{pmatrix}(\bullet_{el})_{ABC} & (o_{in})_{ABC}\\ (...o...) & (...o...)\\ (o^{+}_{el})_{ABC} & (\bullet^{+}_{in})_{ABC}\end{pmatrix}_{d}$$
$$\begin{pmatrix}(\underline{\bullet}_{el})_{ABC} & (\underline{o}_{in})_{ABC}\\ (...\underline{\bullet}...) & (...\underline{\bullet}...)\\ (\underline{o}^{+}_{el})_{ABC} & (\underline{\bullet}^{+}_{in})_{ABC}\end{pmatrix}_{\underline{cl}} \Rightarrow \begin{pmatrix}(\underline{\bullet}_{el})_{ABC} & (\underline{o}_{in})_{ABC}\\ (...\underline{\bullet}...) & (...\underline{\bullet}...)\\ (\underline{o}^{+}_{el})_{ABC} & (\underline{\bullet}^{+}_{in})_{ABC}\end{pmatrix}_{u} \tag{15}$$

where ($\bullet$, $\underline{o}$) are semi-quanta with a phase rotation in the anti-clockwise direction.

The central row may have different configurations in the elastic and inertial characteristics, and may also involve the "Hermitian conjugate" operator.
The IQO-V are oscillators with (n = 2) and are represented by matrices with three rows (1 x 3). The distribution of semi-quanta inside a d-quark can be described as shown in Fig. 11, and that for a u-quark is described in Fig. 12:

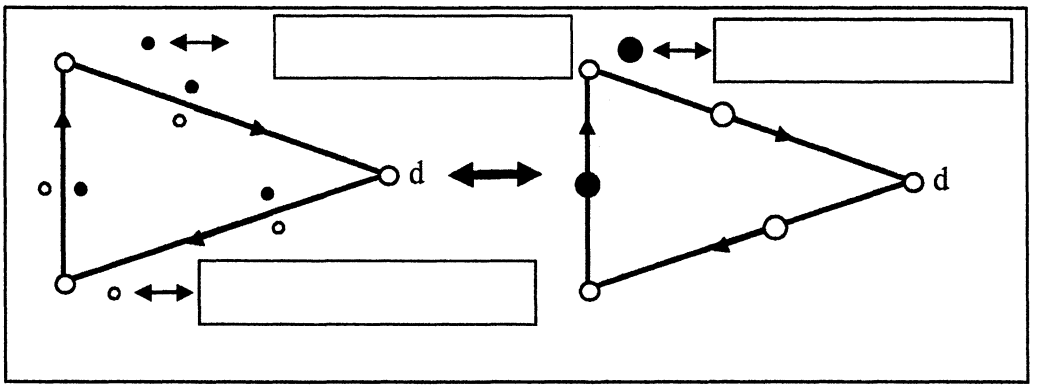

Fig. 11

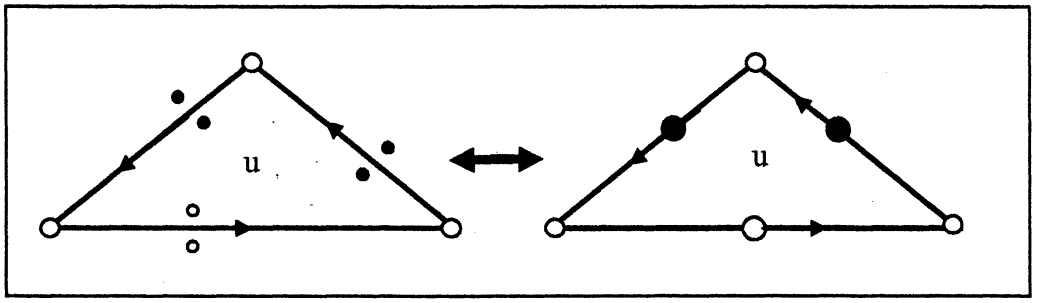

Fig. 12

Recall [1] that an electric charge is based on the probability of detecting a quantum in triangle $P(\bullet)_q$.
From Figs. 11 and 12, it follows: $P(\bullet)_q = [(\text{n quanta})_q / (\text{n sides})]$.
We have that $[P(\bullet)_d = [(1/ 3), P(\bullet)_u = [(2/ 3)]$. The number of empty semi-quanta can be used to indicate if a particular particle is unstable. A u-quark (i.e., 2(o) empty semi-quanta) may be more stable than a d-quark (i.e., 4(o) empty semi-quanta) because the coupling between the IQO of different particles involves a change of energy [(o) ↔ (•)].

In this context, it is worthwhile to compare the composition of protons [p ≡ (u, d, u)] with that of unstable neutrons [n ≡ (d, u, d)].

2.2 The s-quark

Moreover, we noted [1] in the (d) or (u) aureus triangles, it is possible to insert two "sub" aureus triangles of types (d) and (u), as shown in Fig. 13, which are denoted (đ) and (ŭ):

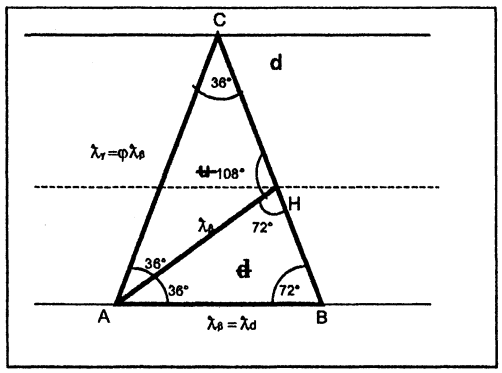

Fig. 13

This geometric possibility in QM will be expressed by the new state physical (|s>) associated with a pair of (đ, ŭ) quarks inserted into a virtual empty quark (q*) of type (d) or (u). A "**virtual**" quark is a quark with only empty semi-quanta (o), while (đ) or (ŭ) indicate a "sub-quark". **The operation of entanglement is indicated by the algebraic operator (⊗), while the operation of "superposition-combination" is indicated by the operator (⊕) [1], [2].** Note that the ⊗-operator involves a composite state of non-separable states, whereas the ⊕-operator involves states that may be separable. We therefore admitted to the existence of a third quark (s), which can be used to express the possibility |s>. This can be written:

$$s = \left[q^* \otimes \left(\breve{u} \otimes \breve{d}\right)\right] \tag{16}$$

This quark is known as the strange quark, and is an overlap of two "internal" (ŭ, đ) quarks as follows: s ≡ [(ŭ⊗đ)] $_{q^*}$. There are two possibility:

- ≡ [(ŭ⊗đ)]$_{d^*}$.

•

$\equiv [(\not{u}\otimes\not{d})]_{u^*}$

An illustration of these configurations is shown in Fig. 14.

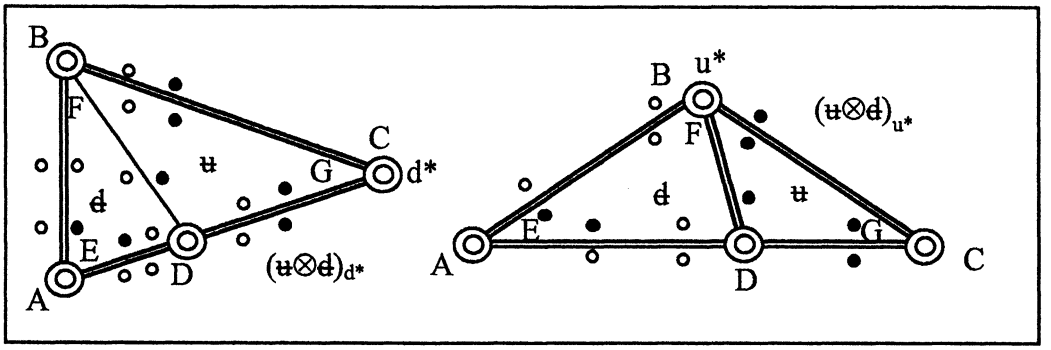

Fig. 14

In the s-quark, the electric charge is determined by the probability of detecting a quantum [(•), (•)] in a triangle. There are nine (9) possible "paths" that the quanta can move through [1]. To have an electric charge, the quanta must be in one of two configurations: $[P(\bullet)_s = (3/9) = (1/3)]$.

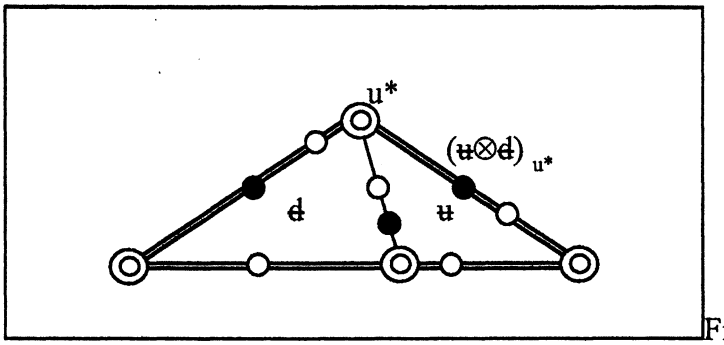

Fig. 15

In the case shown in Fig. 15, the charge of the s-quark is: **Q(s) = ± 1/3**. The two configurations shown in Fig. (14) have equivalent values of electric charge. However, the sign is correlated with the rotation direction of the flow of full semi-quanta: the "tank" quarks (see u* and d*) are empty of full semi-

quanta therefore they cannot impose the charge sign. The charge sign could be given by the secondary quarks; there are two possible configurations (A , B):

$$\left\{\begin{array}{l} Q(s)_{d^*} = Q\left[\left(\not{u}\otimes\not{d}\right)_{d^*}\right] = \left(-\frac{1}{3}\right) \\ Q(\underline{s})_{\underline{d}^*} = Q\left[\left(\underline{\not{u}}\otimes\underline{\not{d}}\right)_{\underline{d}^*}\right] = \left(+\frac{1}{3}\right) \end{array}\right\}_{A(d^*)} \Leftrightarrow \left\{\begin{array}{l} Q(s)_{u^*} = Q\left[\left(\not{u}\otimes\not{d}\right)_{u^*}\right] = \left(-\frac{1}{3}\right) \\ Q(\underline{s})_{\underline{u}^*} = Q\left[\left(\underline{\not{u}}\otimes\underline{\not{d}}\right)_{\underline{u}^*}\right] = \left(+\frac{1}{3}\right) \end{array}\right\}_{A(u^*)} \tag{17}$$

$$\left\{\begin{array}{l} Q(s)_{d^*} = Q\left[\left(\not{u}\otimes\not{d}\right)_{d^*}\right] = \left(+\frac{1}{3}\right) \\ Q(\underline{s})_{\underline{d}^*} = Q\left[\left(\underline{\not{u}}\otimes\underline{\not{d}}\right)_{\underline{d}^*}\right] = \left(-\frac{1}{3}\right) \end{array}\right\}_{B(d^*)} \Leftrightarrow \left\{\begin{array}{l} Q(s)_{u^*} = Q\left[\left(\not{u}\otimes\not{d}\right)_{u^*}\right] = \left(+\frac{1}{3}\right) \\ Q(\underline{s})_{\underline{u}^*} = Q\left[\left(\underline{\not{u}}\otimes\underline{\not{d}}\right)_{\underline{u}^*}\right] = \left(-\frac{1}{3}\right) \end{array}\right\}_{B(u^*)} \tag{18}$$

In the B-configuration the sign could be given by:
$[Q(s)= Q[(\not{u}\otimes\not{d})]_{d^*} = Q(\not{u}) + Q(\not{d}) = +(1/3)]$
Nevertheless the s-quark with charge [+(1/3)] is not generating any K-mesons ($q\underline{s}$,$\underline{q}s$),with [q ≡ (u, d)]. Besides we recall that the secondary quarks are entangled and therefore we cannot have $[Q(s) = Q(\not{u})+ Q(\not{d})]$.
So the literature opts for the first configuration [A(d*), A(u*)] which will give rise to mesons (K).
Nevertheless in QM, the different possibilities [A(d*), A(u*)] must always exist to a certain degree, and indirectly: when the s-quarks couple with other quarks, as we will see later in this paper, there is the possibility that particles identical apparently will have instead different behaviours, see the neutral kaons called: **long-Kaon (K_l) and short-Kaon (K_s)**. All this is very "strange".
The possibility of having a sub-quark pair inserted into an empty quark is the origin of the quantum number called "**strangeness**". The operator acts by unitary transformation U(1); therefore, it may be that:

$$\left\{\begin{array}{l} S(s) = S\left[\left(\not{u}\otimes\not{d}\right)_{q^*}\right] = \pm 1 \\ S(\underline{s}) = S\left[\left(\underline{\not{u}}\otimes\underline{\not{d}}\right)_{q^*}\right] = \mp 1 \end{array}\right\} \tag{19}$$

Next, we determine the strangeness eigenvalues of the sub-quark. Given that there are two secondary quarks inside a primary quark, while considering the symmetry of matter-antimatter and that the eigenvalues redouble, one achieves:

$$\boxed{\begin{pmatrix} s(s)=-1 \\ s(\underline{s})=+1 \end{pmatrix} \Leftrightarrow \begin{pmatrix} s(\not{u})=-\frac{1}{2} \;\; ; \;\; s(\not{d})=-\frac{1}{2} \\ s(\underline{\not{u}})=+\frac{1}{2} \;\; ; \;\; s(\underline{\not{d}})=+\frac{1}{2} \end{pmatrix}} \tag{20}$$

The representative matrix could be:

$$\hat{s}=\left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (o..) & (o..) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{d} \otimes \begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{\bullet}..) & (\underline{\bullet}..) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{u}\right]_{q^*} \tag{21}$$

Then, if $\mathbf{s = [(\not{u}\otimes\not{d})_{d^*}]}$, it is:

$$\boxed{\begin{aligned} \hat{s} &= \left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (o...) & (o...) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{d} \otimes \begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{\bullet}...) & (\underline{\bullet}...) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{u}\right]_{q^*} = \\ &= \left\{\left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (o...) & (o...) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{d} \otimes \begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{\bullet}...) & (\underline{\bullet}...) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{u}\right] \otimes \begin{pmatrix} (o_{el}) & (o_{in}) \\ (o...) & (o...) \\ (o^{+}_{el}) & (o^{+}_{in}) \end{pmatrix}_{d^*}\right\} \end{aligned}} \tag{22}$$

The configurations of s-quark with empties tank quarks and sub-quarks are referred to as the "empty quark" (**Ø-quark**):

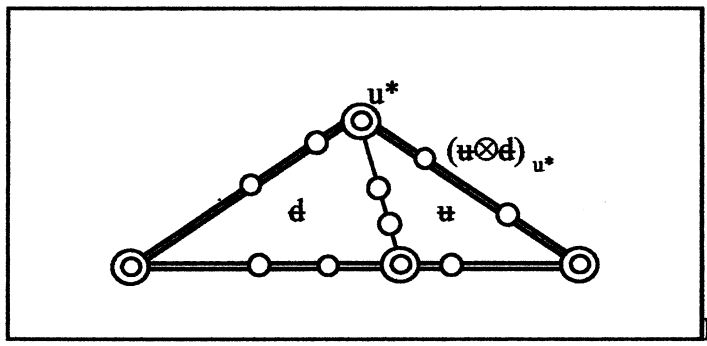

Fig. 16

2.3 The isospin

In QM, a spin operator is assigned to the rotations. The case of the rotation of flow is assigned "**isospin**" (**I**). Because there are two rotational directions of flows, the eigenvalues are ($I_Z = \pm 1/2$), which are similar to the spin ($J = \pm 1/2$), as shown in Fig. 17.

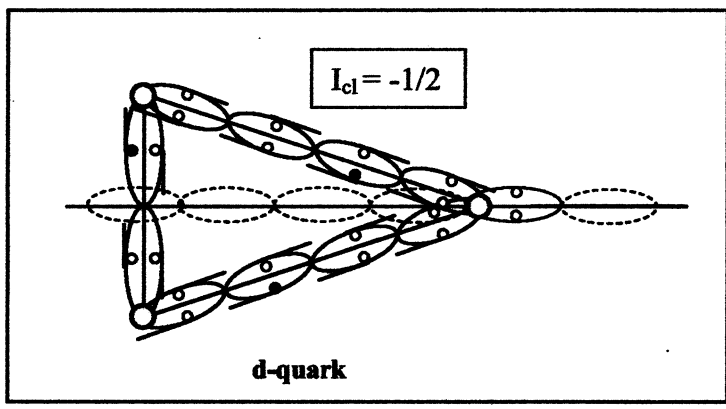

Fig. 17

In a d-quark with an electric charge (Q = -1/3), the phase rotation of the sub-oscillators is in the clockwise direction.

In the same way, the (•) full semi-quanta flow inside a structure with clockwise rotation is [$I_3 \equiv I_{cl} = -1/2$]. In this case, we have:

$$\begin{pmatrix} Q(+) \Rightarrow I_3 = +\frac{1}{2} \\ Q(-) \Rightarrow I_3 = -\frac{1}{2} \end{pmatrix} \qquad (23)$$

In a u-quark with an electric charge (Q = +2/3), the phase rotation of the sub-oscillators is in the anticlockwise direction.
Similarly, the full semi-quanta flow inside a structure with anticlockwise rotation is [$I_3 \equiv I_{\underline{cl}} = -1/2$], as shown in Fig. 18.

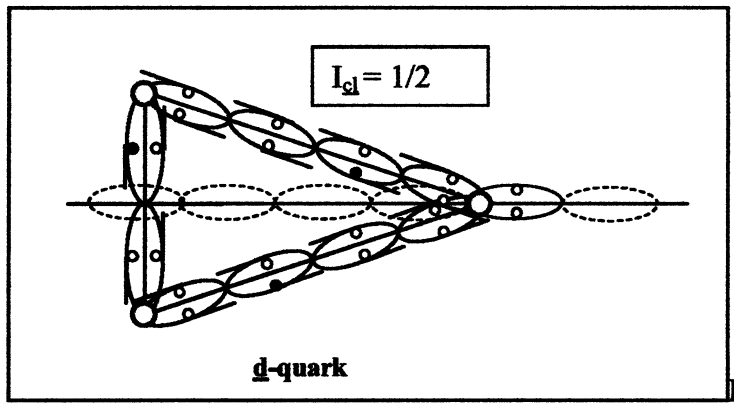

Fig. 18

The isospin I_3 of an s-quark can be calculated by considering the flows (Φ_i) of the semi-quantum current and the entangled structure of IQO. If we recall that the semi-quanta of a d*-quark are empty but with a clockwise phase rotation, it follows that the flow of semi-quantum empties has a value of zero, i.e., $\mathbf{I_3(q^*) = 0}$. Thus, $\mathbf{[I_d(s) = I(d^*) \otimes (I(\bar{u}) \otimes I(\bar{d})]}$:

$$I_3(s) = I_3[d^* \otimes (\bar{u} \otimes \bar{d})] = [I_3(d^*) \oplus I_3(\bar{u}) \oplus I_3(\bar{d})] = \left[(0) + \left(\frac{1}{2}\right) + \left(-\frac{1}{2}\right)\right] = 0 \qquad (24)$$

We now consider the configuration $\mathbf{[I_u(s) = I(u^*) \otimes I(\bar{u}) \otimes I(\bar{d})]}$. In this case, the isospin is:

$$I_3(s) = I_3[u^* \otimes (\bar{u} \otimes \bar{d})] = [I_3(u^*) \oplus I_3(\bar{u}) \oplus I_3(\bar{d})] = \left[(0) + \left(\frac{1}{2}\right) + \left(-\frac{1}{2}\right)\right] = 0 \qquad (25)$$

The two configurations $\mathbf{[I_d(s), I_u(s)]}$ are equivalent in isospin.
The possibility of having a d*-quark or u*-quark with a direction of flow of full semi-quanta that are non-zero results in the meson K. Note that the

configuration **[d* ⊗ (u ⊗ d)]** cannot represent a neutron because two d-quarks cannot be entangled into a neutron. Instead the neutron and proton can be: **n = [(d ⊕ u ⊕ d)] , p = [(u ⊕ d ⊕ u)]**

2.4 (c, b, t) quarks

In this subsection, we consider other possible combinations of sub-quarks.
We can see that the second configuration (see Fig. 14) cannot originate as a new type of "strangeness charge". Instead, there is another possible configuration that includes sub-quark pairs.
One possibility is to insert a pair of ($\underline{u}_2$, $\underline{d}_2$) sub-quarks into one of the two sub-quarks of the pair (u_1,d_1), i.e., (d_1), as shown in Fig. 19. We refer to this configuration as state [Ψ(c)]:

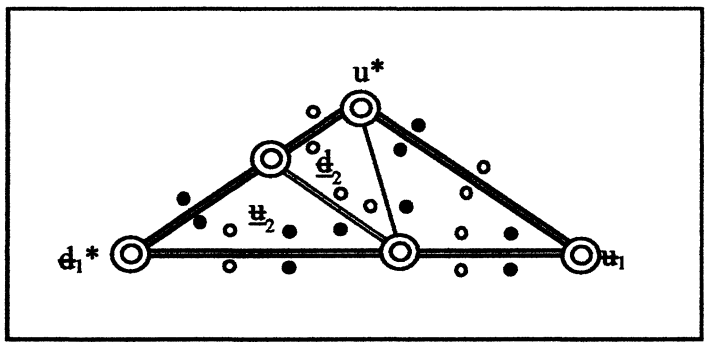

Fig. 19

The mass increases as the number of vertices increases, i.e., [m(c) > m(s) > m(d)]. This because, as the number of real vertices increases, there is an increase in the elastic tension between the IQO. If the elastic tension is increasing in any oscillator, then this increases the frequency or mass.
In this case, the state [Ψ(c)] will be:

$$\Psi(c) = u^* \otimes \left\{\left[\left(d_1^*\right) \otimes \left(\underline{u}_2 \otimes \underline{d}_2\right)\right] \otimes \left[u_1\right]\right\} \qquad (26)$$

and

$$\Psi(c) = u^* \otimes \left\{\left[\left(\underline{\bar{d}}_1^*\right) \otimes \left(\underline{u}_2 \otimes \underline{\bar{d}}_2\right)\right] \otimes \left[\underline{u}_1\right]\right\} = u^* \otimes \left\{\left[\left(\underline{\bar{d}}_1^*\right) \otimes \left(\underline{u}_1\right)\right] \oplus \left[\left(\underline{u}_2 \otimes \underline{\bar{d}}_2\right)\right]\right\} = \\ = \left[u^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] \tag{27}$$

Where we apply the general relation [(a ⊗ **b**) ⊗ **c** = (**a** ⊗ **c**) ⊕ **b**]. That is happening in the interaction ⇔ observation, then (a) can become directly entangled with (c), then (b) becomes separated from (a) and (c).
This possibility is referred to as a "**c-quark**", which has a strangeness of zero:

$$S(c) = S\left[u^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] = \left[S\left(u^*\right) \oplus \left[\left(S(s_1) + S(\underline{s}_2)\right)\right]\right] = \\ = S\left(u^*\right) + \left[(-1) + (+1)\right] = 0 + 0 = 0 \tag{28}$$

The charge is:

$$Q(c) = Q\left[u^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] == \left[Q\left(u^*\right) \oplus \left[\left(Q(s_1) + Q(\underline{s}_2)\right)\right]\right] = \\ = \left(\frac{2}{3}\right) + \left[\left(-\frac{1}{3}\right) + \left(\frac{1}{3}\right)\right] = +\left(\frac{2}{3}\right) \tag{29}$$

and the isospin (see Eq. 24) is:

$$\left\{I_3(c) = I_3\left[u^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] = \left[I_3\left(u^*\right) \oplus \left[\left(I_3(s_1) + I_3(\underline{s}_2)\right)\right]\right] = (0) + [0] = 0\right\} \tag{30}$$

The next possible configuration is (omitting the semi-quanta) shown in Fig. 20.

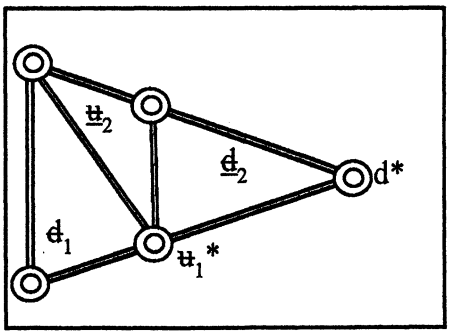

Fig. 20

Its state [Ψ(b)] will be:

$$\Psi(b) = d^* \otimes \left\{\left[\left(u_1^*\right) \otimes \left(\underline{u}_2 \otimes \underline{d}_2\right)\right] \otimes \left[\underline{d}_1\right]\right\} = d^* \otimes \left\{\left[\left(\underline{d}_1 \otimes u_1^*\right) \oplus \left(\underline{u}_2 \otimes \underline{d}_2\right)\right]\right\} = \\ = \left[d^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] \tag{31}$$

This possibility is called a "**b-quark**", which has a strangeness of zero:

$$S(b) = S\left[d^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] = \left[S\left(d^*\right) \oplus \left[\left(S(s_1) + S(\underline{s}_2)\right)\right]\right] = \\ = S\left(d^*\right) + \left[(-1) + (+1)\right] = 0 \tag{32}$$

the charge is:

$$Q(b) = Q\left[d^* \otimes \left(s_1 \oplus \underline{s}_2\right)\right] = \left[Q\left(d^*\right) \oplus \left[\left(Q(s_1) + Q(\underline{s}_2)\right)\right]\right] = \\ = \left(-\frac{1}{3}\right) + \left[\left(-\frac{1}{3}\right) + \left(\frac{1}{3}\right)\right] = -\left(\frac{1}{3}\right) \tag{33}$$

and the isospin is:

$$\left\{I_3(b) = I_3\left[d^* \oplus \left(s_1 \oplus \underline{s}_2\right)\right] = \left[I_3\left(d^*\right) \oplus \left[\left(I_3(s_1) + I_3(\underline{s}_2)\right)\right]\right] = (0) + [0] = 0\right\} \tag{34}$$

There is one more possible combination of sub-quarks:

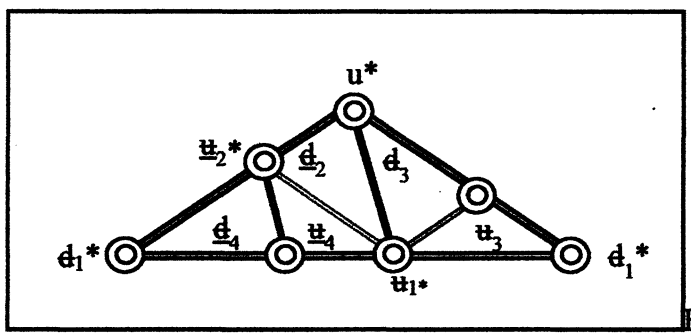

Fig. 21

its state [Ψ(t)], shown in Fig. 21, is defined as follows:

$$\begin{aligned}\Psi(t) &= u^* \otimes \left\{\left[\left(\underline{d}_1^*\right) \otimes \left[\left[\underline{u}_2^* \otimes \left[\left(\underline{u}_4 \otimes \underline{d}_4\right)\right]\right] \otimes \left[\underline{d}_2\right]\right] \otimes \left[\left(\underline{u}_1^*\right) \otimes \left[\underline{u}_2^* \otimes \left(\underline{u}_3 \otimes \underline{d}_3\right)\right]\right]\right]\right\} = \\ &= u^* \otimes \left\{\left[\left(\underline{d}_1^*\right) \otimes \left[\left[\underline{u}_2^* \otimes \left[\left(s_4\right)\right]\right] \otimes \left[\underline{d}_2\right]\right] \otimes \left[\left(\underline{u}_1^*\right) \otimes \left[\underline{u}_2^* \otimes \left(\underline{s}_3\right)\right]\right]\right\} = \\ &= u^* \otimes \left\{\left[\left(\underline{d}_1^*\right) \otimes \left[\left(\underline{s}_2^*\right) \oplus \left(s_4\right)\right] \otimes \left[\left(\underline{u}_1^*\right) \otimes \left[\underline{u}_2^* \otimes \left(\underline{s}_3\right)\right]\right]\right\} = \\ &= u^* \otimes \left\{\left[\left(\underline{s}_2^*\right) \oplus \left(s_4\right)\right] \oplus \left[\left(s_1^*\right) \oplus \left(\underline{s}_3\right)\right]\right\}\end{aligned} \tag{35}$$

Thus:

$$\Psi(t) = u^* \otimes \left\{\left[\left(\underline{s}_2^*\right) \oplus \left(s_4\right)\right] \oplus \left[\left(s_1^*\right) \oplus \left(\underline{s}_3\right)\right]\right\} \tag{36}$$

The t-quark has strangeness of zero:

$$\begin{aligned}S(t) &= S\left\{u^* \otimes \left\{\left[\left(\underline{s}_2^*\right) \oplus \left(s_4\right)\right] \oplus \left[\left(s_1^*\right) \oplus \left(\underline{s}_3\right)\right]\right\}\right\} = \\ &= \left[S\left(u^*\right) \oplus \left[\left(S\left(\underline{s}_2^*\right) + S\left(s_4\right)\right) + \left(S\left(s_1^*\right) + S\left(\underline{s}_3^*\right)\right)\right]\right] = S\left(d^*\right) + \left[(0) + (+0)\right] = 0\end{aligned} \tag{37}$$

the charge is:

$$\begin{aligned}Q(t) &= Q\left\{u^* \otimes \left\{\left[\left(\underline{s}_2^*\right) \oplus \left(s_4\right)\right] \oplus \left[\left(s_1^*\right) \oplus \left(\underline{s}_3\right)\right]\right\}\right\} = \\ &= \left[Q\left(u^*\right) \oplus \left[\left(Q\left(\underline{s}_2^*\right) + Q\left(s_4\right)\right) + \left(Q\left(s_1^*\right) + Q\left(\underline{s}_3^*\right)\right)\right]\right] = \\ &= Q\left(u^*\right) + \left[(0) + (+0)\right] = \left(+\frac{2}{3}\right)\end{aligned} \tag{38}$$

and the isospin is:

$$\begin{aligned}I_3(t) &= I_3\left\{u^* \otimes \left\{\left[\left(\underline{s}_2^*\right) \oplus \left(s_4\right)\right] \oplus \left[\left(s_1^*\right) \oplus \left(\underline{s}_3\right)\right]\right\}\right\} = \\ &= \left[I_3\left(u^*\right) \oplus \left[\left(I_3\left(\underline{s}_2^*\right) + I_3\left(s_4\right)\right) + \left(I_3\left(s_1^*\right) + I_3\left(\underline{s}_3\right)\right)\right]\right] = 0\end{aligned} \tag{39}$$

Considering the number of vertexes, we note that [m(t) > m(b) > m(c)].
There are no other basic quarks because the more complex structures are repetitions of the combinations of fundamental quarks, i.e., (u, d, s) and (c, b, t) quarks. This is easily demonstrable if we note (see the figures) that the

(b, t) quarks consist of **Ø-quarks**, which differentiate the various configurations and cause each to be "unique".

3. The structure of Mesons

3.1 The structure of Mesons π

Mesons are hadrons composed of a quark-antiquark pair. The most elementary are the pions. We may conjecture a IQO structure of Aureus triangles built by couplings between (u) and (d) quarks.
If we recall the proton structure, then we may conjecture the form of the pion shown in Fig. 22, where (u) is the u-antiquark.

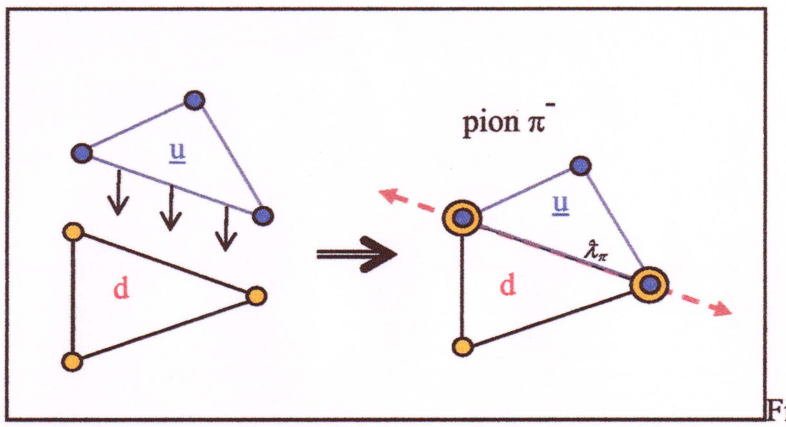

Fig. 22

The coupling between the u- and d-quarks results in a quadrangular structure

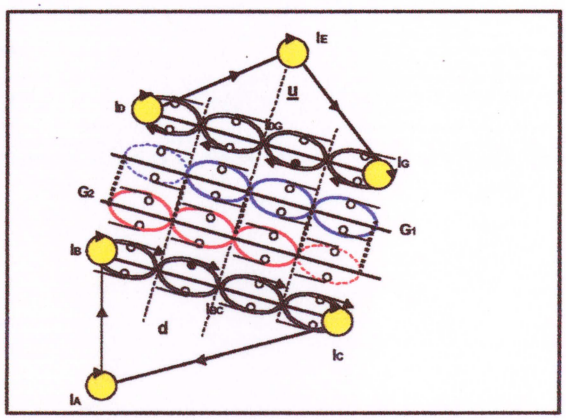

Fig. 23

To link the two (u, d) quarks, it is necessary add a junction IQO between the sub-oscillators of the respective bases. We suspect that the oscillators IQO of the junction are actually "**gluons**" (Fig. 23), where [I_A, I_B, I_C, I_D, I_E, I_G] are the vertices IQO, and (G_1, G_2) are the two gluons (G-IQO) that link the bases. The "red" and "blue" colours of the sub-oscillators may indicate the presence of another "descriptive coordinate" because there are two involved gluons: the "**colour charge**".

This because the reciprocal phase shifts between G-IQO and Q-IQO of the quark structure must not dismantle the quark structure. The figure also indicates the possibility of coupling between the IQO of the quark chains, and between the G-IQO.

The coupling (u ⇔d) is indicated by the combination (⊕) operation of the representative matrices (1 x 3) of the two quarks (see Eq. (15)) while omitting the coupling gluons:

$$\pi^- = \begin{pmatrix} (\bullet_{el})_{ABC} & (o_{in})_{ABC} \\ (...o_{el}...) & (...\bullet_{in}...) \\ (o^+_{el})_{ABC} & (\bullet^+_{in})_{ABC} \end{pmatrix}_d \oplus \begin{pmatrix} (o_{el})_{DEG} & (\bullet_{in})_{DEG} \\ (...\bullet_{el}..) & (...o_{in}...) \\ (\bullet^+_{el})_{DEG} & (o^+_{in})_{DEG} \end{pmatrix}_{\underline{u}} \tag{40}$$

Note in the sub-oscillator chain of the base (base BC and DG), the clockwise rotation of the phase is associated with a negative electric charge (Q), while the directional arrows at the sides indicate a clockwise rotation of the semi-quanta flow or (isospin I_3). The electric charge is given by the probability $P(\bullet)_\pi$ of detecting a quantum in the quadrangular structure. From Fig. 14 and Fig. 30, it follows that $P(\bullet)_\pi = [(\text{n quanta})_\pi / (\text{n sides})_\pi]$:

$$P(\bullet)_\pi = \left[\frac{n(\bullet)}{n_{(sides)}}\right]_\pi = \left\{\left[\frac{n(\bullet)}{n_{(sides)}}\right]_u + \left[\frac{n(\bullet)}{n_{(sides)}}\right]_d\right\} = \left\{\left[\frac{2}{3}\right]_u + \left[\frac{1}{3}\right]_d\right\} = +1 \tag{41}$$

It follows that:

$$\left(\begin{array}{l}\left\{P[\underline{u}\oplus d]=P(\underline{u})+P(d)=\frac{2}{3}+\frac{1}{3}=+1\right\}\Leftrightarrow\left\{P(\pi^-)=+1\right\}\\ \left\{P[u\oplus\underline{d}]=P(u)+P(\underline{d})=\frac{2}{3}+\frac{1}{3}=+1\right\}\Leftrightarrow\left\{P(\pi^+)=+1\right\}\end{array}\right) \tag{42}$$

Then, the electric charge will be:

$$\left(\begin{array}{l}\left\{Q[\underline{u}\oplus d]=Q(\underline{u})+Q(d)=-\frac{2}{3}-\frac{1}{3}=-1\right\}\Leftrightarrow\left\{Q(\pi^-)=-1\right\}\\ \left\{Q[u\oplus\underline{d}]=Q(u)+Q(\underline{d})=+\frac{2}{3}+\frac{1}{3}=+1\right\}\Leftrightarrow\left\{Q(\pi^+)=+1\right\}\end{array}\right) \tag{43}$$

About the isospin, we note in each side a clockwise direction of flow:

$$\left(\begin{array}{l}I(\pi^-)=I[\underline{u}\oplus d]=I(\underline{u})+I(d)=-\frac{1}{2}-\frac{1}{2}=-1\\ I(\pi^+)=I[u\oplus\underline{d}]=I(u)+I(\underline{d})=+\frac{1}{2}+\frac{1}{2}=+1\end{array}\right) \tag{44}$$

The form of the pion is shown in Fig. 24, where the "**decay axis**" and two different configurations are highlighted to indicate the passage of time (i.e., the possible rotation of quark u around the decay axis). The decay axis is coincident whit the propagation axis of structure [$\boldsymbol{\pi = (u \oplus d)}$] and only long this axis it happens the possible decay of the particle:

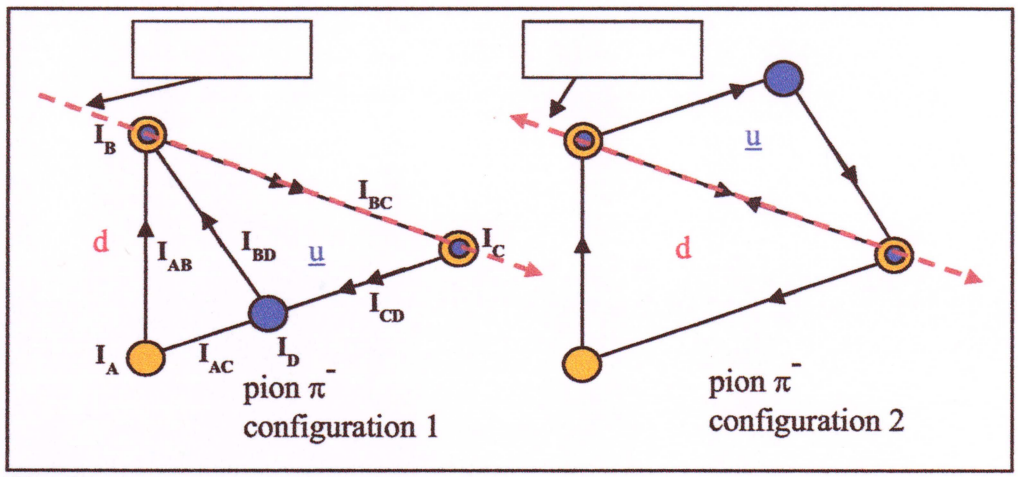

Fig. 24

We now hypothesize the form of the neutral pion: **$[(\pi^0)]$**.
To have a neutral configuration, we can combine two couples [(u, d), (u, d)]. It follows that $(\pi^0) = [(u\underline{d}) \otimes (\underline{u}d)]$, where ($\otimes$) is the "**entanglement operator**".
We can also write: $(\pi^0) = [(u\underline{d}) \otimes (\underline{u}d)]$.
Here, a new property of the $\otimes$-operator emerges, namely, that the entanglement states themselves penetrate, which can be written as:
$(\pi^0) = [(u\underline{d}) \otimes (\underline{u}d)] = [(\pi^+) \otimes (\pi^-)]$
The existence of penetration implies that $[m(\pi^0) \approx m(\pi^{\pm})]$, which leads to Fig. 25, where the possible ($\approx$ 99 % probability) electromagnetic decay of $[(\pi^0)]$ along the one and only "axis of decay", i.e. **$[(\pi^0) \Rightarrow \gamma + \gamma]$**, is indicated:

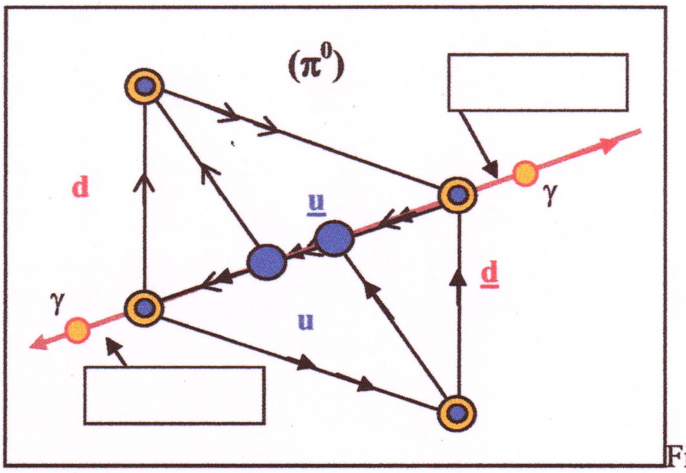

Fig. 25

The representative matrix is

$$\pi^{\circ} = \left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (o_{el}) & (\bullet_{in}) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{d} \oplus \begin{pmatrix} (o_{el}) & (\bullet_{in}) \\ (\bullet_{el}) & (o_{in}) \\ (\bullet^{+}_{el}) & (o^{+}_{in}) \end{pmatrix}_{\underline{u}} \right] \otimes \left[\begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{o}_{el}) & (\underline{\bullet}_{in}) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{\underline{d}} \oplus \begin{pmatrix} (\underline{o}_{el}) & (\underline{\bullet}_{in}) \\ (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{\bullet}^{+}_{el}) & (\underline{o}^{+}_{in}) \end{pmatrix}_{u} \right] \qquad (45)$$

The ⊗-operator operates on matrices much like the ⊕-operator. If we adopt the algebraic calculus of matrices and that showed in eq. (10), all this leads to one of the possible decay of pion (π^0):

$$
\begin{aligned}
\pi^{\circ} &= \left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (o_{el}) & (\bullet_{in}) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{d} \oplus \begin{pmatrix} (o_{el}) & (\bullet_{in}) \\ (\bullet^{+}_{el}) & (\bullet^{+}_{in}) \\ (\bullet^{+}_{el}) & (o^{+}_{in}) \end{pmatrix}_{\underline{u}}\right] \otimes \left[\begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{\underline{d}} \oplus \begin{pmatrix} (\underline{o}_{el}) & (\underline{\bullet}_{in}) \\ (\underline{\bullet}_{el}) & (\underline{\bullet}_{in}) \\ (\underline{\bullet}^{+}_{el}) & (\underline{o}^{+}_{in}) \end{pmatrix}_{u}\right] = \\
&= \left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (o_{el}) & (\bullet_{in}) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{d} \oplus \begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (\underline{\bullet}^{+}_{el}) & (\underline{o}^{+}_{in}) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{\underline{d}}\right] \oplus \left[\begin{pmatrix} (o_{el}) & (\bullet_{in}) \\ (\bullet^{+}_{el}) & (\bullet^{+}_{in}) \\ (\bullet^{+}_{el}) & (o^{+}_{in}) \end{pmatrix}_{\underline{u}} \oplus \begin{pmatrix} (\underline{o}_{el}) & (\underline{\bullet}_{in}) \\ (\underline{\bullet}_{el}) & (\underline{\bullet}_{in}) \\ (\underline{\bullet}^{+}_{el}) & (\underline{o}^{+}_{in}) \end{pmatrix}_{u}\right] = \\
&= \left\{\left[\begin{pmatrix} (o_{el}) & (\bullet_{in}) \\ (\underline{\bullet}^{+}_{el}) & (\underline{o}^{+}_{in}) \end{pmatrix} + \begin{pmatrix} (\underline{o}_{el}) & (\underline{\bullet}_{in}) \\ (\bullet^{+}_{el}) & (o^{+}_{in}) \end{pmatrix}\right]_{\gamma} + \begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix}_{\gamma^{*}}\right\} + \\
&+ \left\{\left[\begin{pmatrix} (\bullet_{el}) & (o_{in}) \\ (\underline{o}^{+}_{el}) & (\underline{\bullet}^{+}_{in}) \end{pmatrix} + \begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{o}_{in}) \\ (o^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}\right]_{\gamma} + \begin{pmatrix} (\underline{\bullet}_{el}) & (\underline{\bullet}_{in}) \\ (\bullet^{+}_{el}) & (\bullet^{+}_{in}) \end{pmatrix}_{?}\right\} = \\
&= \hat{\gamma} + \hat{\gamma} + (\gamma^{*} + ?)
\end{aligned}
\tag{46}
$$

If we then add virtual pairs ($\gamma'_v + \gamma'_v$) of photons (with only ($\bullet$) full semi-quantum), we can transform the element ($\gamma^* + ?$) into a virtual pair ($\gamma_v + \gamma_v$).

3.2 The structure of K-mesons

We recall that the s-quark does not exist in isolation, but must be inserted into a d- or u-quark, as shown in Fig. 26, where the multiple circles indicate the overlapping of multiple IQO-vertices.

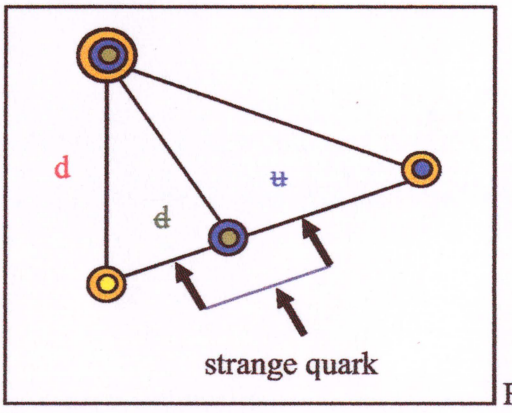

Fig. 26

It will then be possible to form two different particles with strange quarks [s ≡ [($\underline{u}$ ⊗ $\underline{d}$)]]. The first is built with a d-quark (primary quark) and the other with a u-quark (primary quark).
The s-configuration can be enclosed in a non-empty antiquark, such as a $\underline{u}$-quark, by operator (⊕): **[$\underline{u}$ ⊕ ($\underline{u}$ ⊗ $\underline{d}$)]**. For the symmetry of matter-antimatter, we also have **[u ⊕ ($\underline{u}$ ⊗ $\underline{d}$)]**.
The introduction of secondary quarks inside the primary (u, d) quarks admits two different possibilities (Ψ_u, Ψ_d). If we desire these states to become particles, actually mesons, then we may admit the combination quark-antiquark, as follows:

$$\begin{pmatrix} \Psi_u = [u \oplus (\underline{u} \otimes \underline{d})] = (u \oplus \underline{s}) \equiv (u\underline{s}) \;\; ; \;\; \Psi_d = [d \oplus (\underline{u} \otimes \underline{d})] = (d \oplus \underline{s}) \equiv (d\underline{s}) \\ \Psi_{\bar{u}} = [\underline{u} \oplus (\underline{u} \otimes \underline{d})] = (\underline{u} \oplus s) \equiv (\underline{u}s) \;\; ; \;\; \Psi_{\bar{d}} = [\underline{d} \oplus (\underline{u} \otimes \underline{d})] = (\underline{d} \oplus s) = (\underline{d}s) \end{pmatrix} \quad (47)$$

where (s) is the quark with strangeness (s).
We now consider which structures correspond to actual particles. A structure of coupled IQO must have a well-defined value of charge Q and isospin I_3, which will be due to all possible paths of semi-quanta. This happens in mesons that have a structure that includes a quark-antiquark pair. Particles with strangeness must be combinations of quark-antiquarks. If we consider the configuration (Ψ_d) = [d ⊕ ($\underline{u}$ ⊗ $\underline{d}$)]; in order to flow in the clockwise direction (→), we give the value of isospin [(I_3) = -1/2]; to flow in anticlockwise direction (←) the value of isospin [(I_3) = +1/2]:

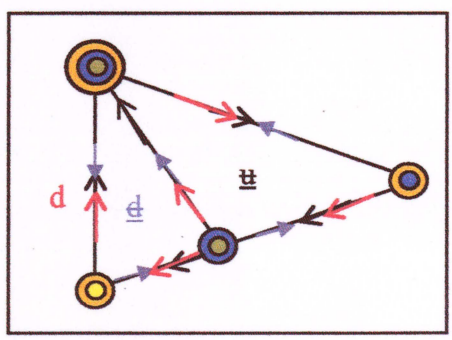

Fig. 27

Next, we determine the charge sign and I_3. The isospin I_3 of the s-quark has already been calculated.

The s-quark, which becomes entangled with the u-quark or d-quark, has:
$I_3\,[(\not{u} \oplus \not{d})]_{q^*} = I_3(\not{u}) + I_3(\not{d}) = I_3(\not{s}) = 0$
The isospin of Ψ_d will be:

$$\left(\begin{array}{l} I(\Psi_d) = I[d \oplus \underline{s}] = I(d) + I(\underline{s}) = -\frac{1}{2} + 0 = -\frac{1}{2} \\ I(\underline{\Psi}_d) = I[\underline{d} \oplus s] = I(\underline{d}) + I(s) = +\frac{1}{2} + 0 = +\frac{1}{2} \end{array} \right) \tag{48}$$

The charge is:

$$\left(\begin{array}{l} \{Q(\Psi_d) = Q[d \oplus \underline{s}] = 0\} \Rightarrow \left\{ Q(d) + Q(\underline{s}) = -\frac{1}{3} + \frac{1}{3} = 0 \right\} \\ \{Q(\underline{\Psi}_d) = Q[\underline{d} \oplus s] = 0\} \Rightarrow \left\{ Q(\underline{d}) + Q(s) = +\frac{1}{3} - \frac{1}{3} = 0 \right\} \end{array} \right) \tag{49}$$

The structure Ψ_d has the same values of charge and I_3 as the Kaon, which is the neutral K-meson ➔ $\boxed{\Psi_d = [d \oplus (\not{u} \otimes \underline{\not{d}})] = (d \oplus \underline{s}) \equiv K^\circ}$ although there is also another possibility: $\underline{K}^\circ = [\underline{d} \oplus (\not{u} \otimes \not{d})]$. In this case, the entanglement between the s-quark and u- or d-quarks constructs the K-meson or "Kaon". Then, Eq. (47) becomes:

$$\left(\begin{array}{lll} K^+ = [u \oplus (\underline{\not{u}} \otimes \underline{\not{d}})] = (u \oplus \underline{s}) & ; & K^\circ = [d \oplus (\underline{\not{u}} \otimes \underline{\not{d}})] = (d \oplus \underline{s}) \\ K^- = [\underline{u} \oplus (\not{u} \otimes \not{d})] = (\underline{u} \oplus s) & ; & \overline{K}^\circ = [\underline{d} \oplus (\not{u} \otimes \not{d})] = (\underline{d} \oplus s) \end{array} \right) \tag{50}$$

The Kaon is a structure $(q_i - \underline{q}_j)$. When the structure of the Kaon includes a pair of secondary quarks, we obtain the charge of the s-quark that is coincident with that of Eq. (49):

$$\left(\begin{array}{l} \{Q(K^\circ) = Q[d \oplus \underline{s}] = 0\} \Rightarrow \left\{ Q(d) + Q(\underline{s}) = -\frac{1}{3} + \frac{1}{3} = 0 \right\} \\ \{Q(\underline{K}^\circ) = Q[\underline{d} \oplus s] = 0\} \Rightarrow \left\{ Q(\underline{d}) + Q(s) = +\frac{1}{3} - \frac{1}{3} = 0 \right\} \end{array} \right) \tag{51}$$

In this case, the isospin will be given by Eq. (48):

$$\begin{pmatrix} I(K^{\circ}) = I[d \oplus \underline{s}] = I(d) + I(\underline{s}) = -\frac{1}{2} + 0 = -\frac{1}{2} \\ I(\overline{K}^{\circ}) = I[\underline{d} \oplus s] = I(\underline{d}) + I(s) = +\frac{1}{2} + 0 = +\frac{1}{2} \end{pmatrix} \tag{52}$$

The strangeness (s) of the Kaon K° is:

$$\begin{pmatrix} \{S(K^{\circ}) = S[d \oplus \underline{s}] = S[d \oplus (\underline{u} \otimes \underline{d})] = S[d \oplus [(S(\underline{u}) + S(\underline{d}))]] = S(d) + (+1) = +1\} \\ \{S(\overline{K}^{\circ}) = S[\underline{d} \oplus s] = S[\underline{d} \oplus (u \otimes d)] = S[\underline{d} \oplus [(S(u) + S(d))]] = S(\underline{d}) + (-1) = -1\} \end{pmatrix} \tag{53}$$

In same way, we have:

$$\begin{pmatrix} \{S(K^{+}) = S[u \oplus \underline{s}] = S[u \oplus (\underline{u} \otimes \underline{d})] = +1\} \\ \{S(K^{-}) = S[\underline{u} \oplus s] = S[\underline{u} \oplus (u \otimes d)] = -1\} \end{pmatrix} \tag{54}$$

Next, we illustrate the geometric structure of a K^{+}-meson. Inside a u-quark, we can insert the strange pair ($\underline{u}$, $\underline{\bar{d}}$):

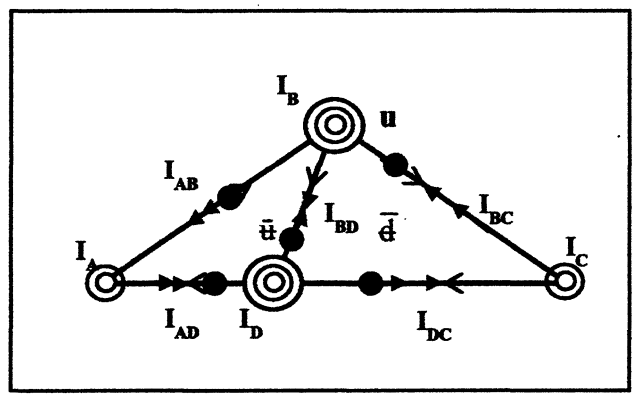

Fig.28

Note (see Fig. 15) that in all sides of the structure, the probability of finding a quanta or pair (•,•) with anticlockwise rotation phase is one. This because the

primary quark (u-quark) is no longer empty, and the total charge is [Q = +1]. As was the case for the pion, the electric charge is due to the u- and $\underline{d}$-quarks:

$$\left(\begin{array}{l} Q(K^+)=+1 \Leftrightarrow Q[u \oplus \underline{s}]=Q(u)+Q(\underline{s})=+\frac{2}{3}+\frac{1}{3}=+1 \\ Q(K^-)=-1 \Leftrightarrow Q[\underline{u} \oplus s]=Q(\underline{u})+Q(s)=-\frac{2}{3}-\frac{1}{3}=-1 \end{array}\right) \tag{55}$$

and the isospin I_3:

$$\left(\begin{array}{l} I(K^+)=I_3[u \oplus \underline{s}]=I(u)+I(\overline{\underline{d}})+I(\overline{\underline{u}})=+\frac{1}{2}+\frac{1}{2}-\frac{1}{2}=+\frac{1}{2} \\ I(K^-)=I[\underline{u} \oplus s]=I(\overline{u})+I(\underline{d})+I(\underline{u})=-\frac{1}{2}-\frac{1}{2}+\frac{1}{2}=-\frac{1}{2} \end{array}\right) \tag{56}$$

Conclusion

The combination of (u, d) quarks in the structure of a pion allows us to determine the structure of light mesons. Once the structure of (s, c, b, t) quarks is known, it is then possible to define the structure of all mesons. In a future work, we will describe the structures of strange mesons and other more massive mesons and even Barions. For example we shall give there the structures of Proton, neutron and Xi-particle, as follows:

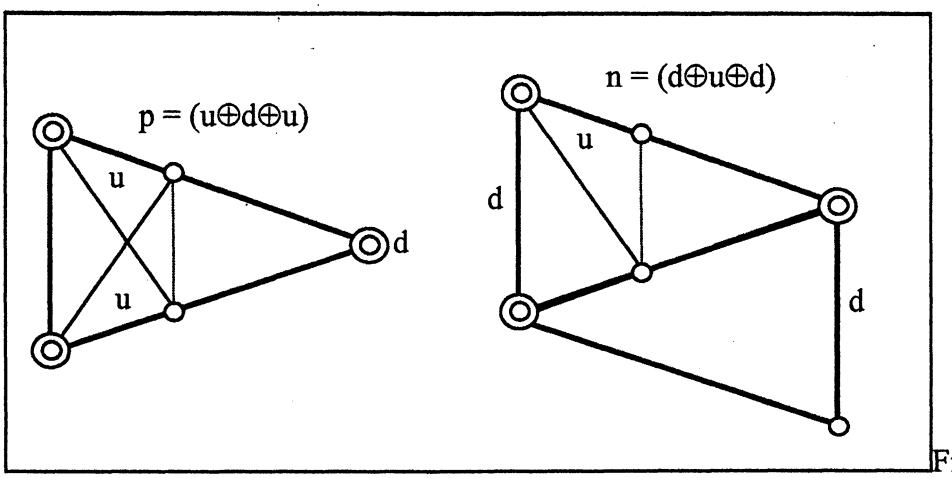

Fig. 29

Combining two c-quarks (you see fig.19) with u-quark one obtains:

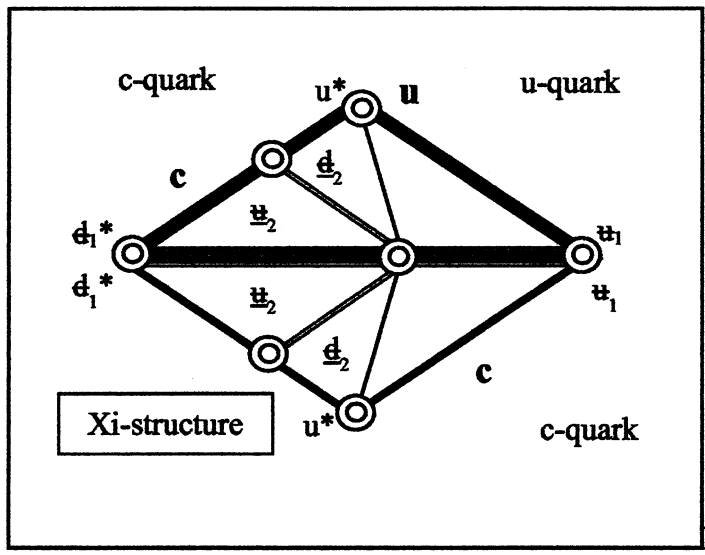

Fig. 19

Using our method of combining quarks, we believe it is possible to determine the mass values of hadrons and their possible decays. In addition, by using the different possible combinations and configurations of three quarks, it will be possible to calculate the masses of barions.

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